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OF THE SUNS."
Tennyson.

PHYSICAL GEOGRAPHY.

BY
SYDNEY B. J. SKERTCHLY, F.G.S.,
H.M. Geological Survey.

Third Edition.

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PREFACE.

The preparation of this little work has for nearly a year occupied the evening hours of days spent in the arduous but pleasant duties of a field geologist. As the first of a new series of Science Manuals, it is necessary to enter somewhat in detail into the scope and aim of the volumes it is proposed to issue from time to time. They are intended to embrace sufficient of the subjects they treat of, to render them available for science students, whether in attending collegiate courses, science classes, or working privately; at the same time they are issued at such a price as to place them within the reach of elementary schools. The matter and mode of treatment, it is hoped, will be found equal to those of larger manuals, among which we trust these volumes may hold an honourable place. The style is simple without falling into the *de haut en bas* system, which neither pleases the junior scholar, nor commands the respect of senior students.

Respecting the present work, which may be taken as a type of those to follow, the author has spared no pains to make it essentially original. He has referred wherever possible to the original memoirs, and while existing text-books have been consulted with regard to treatment, the matter they contain has only been drawn upon in cases where either the facts or deductions were new. All the calculations have been verified afresh, and in this way errors have been avoided which have been continually reproduced in consequence of this great but necessary labour being ignored. As one instance of the utility of this expenditure of time, the author may be allowed to quote the case of so simple a calculation as that of the weight of the ocean. Sir John Herschel in his work upon Physical Geography, by an oversight has estimated the whole surface of the earth, instead of merely the existing water surface, as covered by an ocean four miles deep. The result of course gives a total far too great, and as Sir John's high authority has been quoted in more than one work, it may be as well to call attention to this fact. The author communicated with Professor A. S. Herschel, the son of the great astronomer, respecting this and other similar errors, and begs most cordially to acknowledge the courtesy and assistance he has received from him. The corrected totals, as estimated by the author and verified by Professor Herschel, are embodied in the present work, and will also be inserted in future editions of Sir John's book.

Some of the points to which attention is directed are as follow:—

1. The proofs of the earth's rotation have been partly revived from Fergusson, with additions, as in the calculated velocity of the fixed stars on the supposition of their revolving about the earth.

2. The motions of nutation, precession, etc., have been simply expounded as they have assumed great importance lately on account of their bearing upon the subject of climatal change.

3. The mode of illustrating the measurement of degrees on the earth's surface is new.

4. The simple laws expounding the theory of waves have been deduced from the tables of the Astronomer Royal, and so far are new.

5. Notwithstanding all that has been written concerning the origin of Ocean Currents, the author still believes the causes stated in the text to be the true ones.

6. The classification of springs is original, and geological friends must judge how far the adoption of the word "transtratic" was warranted.

7. Lakes are treated from a Geological as well as from a Geographical point of view.

8. Attention has been directed to the presence of the *atmospheric cold region*, since the snow-line only is usually treated.

9. The phenomenon of dry fogs is introduced.

10. In the illustration to the article on Mirage, the author's own experience has been given as adding new examples to the stock, and as affording good illustrations of the subject.

11. In other cases he has adduced his own personal observations, not because they are better than others, but because "book-making" has caused the standard illustrations to be recopied again and again.

12. The annual distribution of temperature is explained by describing the isotherms of 32° and 77° at different seasons of the year.

13. Great care has been expended in the selection of headings to the various divisions of the subjects.

14. A synoptical index is appended, by the aid of which the student will be able at once to refer to any portion of the work.

15. The derivation of every technical term is given.

The sections on Geological Relations and Life are treated as fully as space would admit, which must be the excuse for their being treated in so "general" a style.

The author acknowledges with gratitude the assistance he has received from Professor A. S. Herschel, B.A., F.R.A.S., in affording him valuable matter, as will be seen in the work, and for guiding him clear of at least one serious error; to the Astronomer Royal for correcting the proofs of the article on the Theory of the Waves; and to Mr. H. W. Bristow, F.R.S., etc., director of the Geological Survey of England, Mr. E. Best, and other of his colleagues, for the interest they have taken in the work.

S. B. J. S.

H.M. Geological Survey,
May, 1872.

ADVERTISEMENT TO SECOND EDITION.

We are gratified to find that a new edition of this work has been so rapidly called for. The sweeping condemnation of cheap text-books on science by the Department of Science and Art, has induced us to take our stand upon the grounds stated on the back of the title-page, and to modify the title of the series.

Sept., 1872.

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PHYSICAL GEOGRAPHY.

INTRODUCTION.

Relations with the Sciences.—Physical Geography cannot strictly be termed a *science*. It is rather a collection from other sciences of those facts which relate to the earth, especially as it exists at the present day. It deals with the earth as a planet, having regard to its size and motions; that is, it includes that portion of *Astronomy* which relates to the earth. It inquires into the distribution of land and sea with their varied aspects of plains and mountains, valleys and hills, their ocean currents, and rivers; and in seeking the causes of these things it encroaches upon the science of *Geology*. From *Chemistry* the Physical Geographer gleans information respecting the composition of the earth, the sea, and the atmosphere. The science of *Physics* teaches him the nature of the earth's magnetism, and its electrical conditions, the properties of air, of light, and of heat. *Zoology* and *Botany* (or *Biology*, as these allied sciences are called) yield their facts as to the distribution of animal and plant life, and the conditions favourable or unfavourable to their development. In short, there is no science but what yields some of its facts to Physical Geography; hence it is that some knowledge of these sciences is necessary in order fully to realize the true nature of the different *phenomena*[1] which the study of Physical Geography presents to our view.

---

[1] Gr., *phainomenon*, an appearance. Sing. *phenomenon*.

Definition.—The word *Geography*[1] is derived from two Greek words which signify, *to write about the earth.* The word *Physical*[2] is also from the Greek, and means *natural;* so that Physical Geography is a description of the natural earth, as distinct from *Political* Geography which treats solely of the earth in its relations to man.

CHAPTER I.

ASTRONOMICAL RELATIONS.

Apparent Motion of the Heavenly Bodies.—Above and all around us there appears a vaulted arch called the *firmament*[3] or sky. Rising overhead to an immense height, it seems to approach the earth on all sides and at length to rest upon it miles away, along the circular line which bounds our vision. This line is the *horizon.*[4]

By day the firmament is of crystal blue and is illuminated by a brilliant body called the *sun,* which sweeps through the sky, rising above the eastern horizon in the morning and setting below its western verge in the evening. By night the sky is still blue but intensely dark in tint, and is lighted very feebly, as compared with the day, by the *moon,* a body apparently about the same size as the sun, and by thousands of glittering points called *stars,* which are scattered in profusion over its entire surface. The moon rises in the east and sets in the west, like the sun, and some of the stars do likewise. The rest never seem to rise and set, but sweep in circles through the sky, without dipping below the horizon.

---

[1] *Ge,* the earth, and *grapho,* to write.

[2] *Physis,* nature.

[3] L., *firmamentum,* a translation of the Hebrew word *rakia,* meaning, *that which is spread out.*

[4] Gr., *horizo,* to bound.

Closer observation will show that the movements of the moon and stars are not precisely alike. The stars in their course never appear to approach or recede from one another, but maintain the same relative distances apart; while the moon traces a course among the stars, drawing away from some, approaching and even passing over others. So that while the stars seem to be fixed in the firmament and to revolve with it round the earth, the moon, besides partaking of this motion, appears to have a movement of its own. Some few of the stars seem also to possess a movement of their own and to wander among the others; and hence they are called *planets*, from the Greek word *planētēs*, a wanderer, while the rest are known as *fixed stars*.

It will likewise be observed that there is a point in the heavens round which these fixed stars revolve, the circles which they describe growing larger as the stars are more distant from it. In the latitude of London this point is not exactly overhead but is distant therefrom 38½° in the direction of the northern horizon. Hence it follows that stars situated at a distance from this point or *axis*[1] *of revolution*[2] perform part of their journey below the horizon, thus causing the phenomena of rising and setting above described. Close to this axis is a star, round which therefore all the others appear to revolve; this star is called the *Pole Star*.[3]

Such are the appearances which the face of the heavens presents to us by night, and for a long time it was considered, very naturally, that the sun, the moon, and the stars were fixed at one and the same distance in a solid crystal sphere which revolved about our earth as a centre. But the peculiar and independent motions of the sun, the moon and the planets were not so easily explained, and it was reserved for other ages to link all these phenomena together and explain them by a *theory*[1] which should agree with all the facts.

---

[1] L., the *axle*, or line on which anything turns.

[2] L., *re*, back, and *volvo*, to roll—to turn or roll back or round anything.

[3] Gr., *poleo*, to turn.

Real Motion.—It requires but slight consideration to see that the revolutions above described would result if the earth had a motion in an opposite direction to that in which the stars appear to travel, that is, if the earth revolved in a direction from west to east upon an axis which if prolonged would reach the Pole Star. This reversal in the direction of the apparent motion is precisely the same as takes place in a railway train, where the trees and hedges seem to fly past in the contrary direction to that in which the train is moving. That the earth really has this motion may be considered as proved from a consideration of the following details:—

1. If the sun and the planets revolve round the earth, then the larger bodies revolve about the smaller, and are influenced by it, without its being influenced by them in return. This is as absurd as to "suppose that six cannon balls might be projected into the air, and that five of them should fall to the ground; but the sixth, which is neither the highest nor the lowest, should remain suspended in the air without falling, and the earth move round about it" (*Fergusson*).

2. If the stars revolve about the earth, the forces by which they revolve are not directed towards the earth, but to the centre of the circles which the stars describe. That is, the forces would be directed to no

---

[1] Gr., *theoreo*, to view. A theory is an explanation resulting from viewing or examining anything.

central body upon which they physically depend, which is absurd.

3. If the heavenly bodies revolve about the earth in 24 hours as they appear to do, those which are farthest from the earth must revolve the quickest. The moon, which is the nearest of those bodies, would have to travel at the rate of about 60,000 miles an hour. The sun would move at the hourly speed of about 23,250,000 miles. The nearest fixed star (*α Centauri*) at about 4,750,000,000,000 miles an hour, and one of the few other stars (61 *Cygni*) whose distance has been measured would have to fly at the rate of double this, or about 8,702,940,000,000 miles in the hour. These stupendous velocities are inconceivable, and when we consider they represent only a few of the *nearest* of the heavenly bodies, it is apparent that they cannot revolve about the earth.

4. The sun, the moon, and the planets revolve upon their own axes; and the earth, which is a similar body, might be presumed to do the same.

5. The rotation of the earth has been proved experimentally. A pendulum always vibrates in the same plane. But as the earth moves under the pendulum it appears to change its direction of vibration, and to move in the opposite direction to the rotation of the earth.

We may then, consider it proved beyond reasonable doubt that the earth revolves upon its axis once in 24 hours. This revolution of the earth is called the *diurnal rotation,*[1] because it occupies one day. Day and night are caused by a given portion of the surface being alternately presented towards and removed away from the sun.

Shape of the Earth.—We will now pause to consider what hitherto we have left untouched, namely, the *shape* or *figure* of the earth. From what has just been said, we may consider the earth as spinning round in much the same manner as a marble twirled between the thumb and finger. Now when the particles composing such a spinning body are free to move among themselves, as when in a liquid state, they always assume a definite form, and that form is a sphere or ball more or less flattened about the extremities of the axis upon which it turns. Drops of water whirled from a spinning top are an illustration of this, but the sparks which fly from a blacksmith's anvil are better suited to show it, for on cooling they can be handled. The science of geology tends to show that the earth presents every appearance of having cooled down from a fluid state, and moreover that the central portions of the earth are still hot. Such being the case we might expect that the earth, like the spark (which it resembles in still other points), would have assumed some such form; and the most careful measurements show that it is really the case, and that the earth is actually an orange-shaped body, flattened towards the *poles*, which are the extremities of its axis of rotation. This shape is known as an *oblate spheroid.*[1]

---

[1] L., *dies*, a day. L., *rotatio*, to turn round like a wheel (*rota*).

The rotundity of the earth may be proved in the following ways:—

1. A ship leaving port on a clear day does not eventually become lost in dim distance, but sinks from sight, the hull going first and the sails gradually following. Just as, to a spectator the wheels of a carriage going over a hill are first lost to view, and then the body of the vehicle itself.

2. Vessels are continually sailing round the world

---

[1] If the earth were perfectly round it would be a *sphere;* not being so it is a *spheroid;* if the poles were *pulled* out instead of flattened it would be a *prolate spheroid.* Gr., *sphaira*, a globe, and *eidos*, like. L., *ob*, against, *latum*, borne or brought; *pro*, forth, and *latum*.

in an east and west direction, thus proving its rotundity in that direction. The course for outward bound vessels to Australia is round the Cape of Good Hope, that is eastward; and the homeward course, round Cape Horn is still eastward. So that a vessel, when it arrives in England after such a voyage, has been sailing in the same direction on both passages, and has hence sailed right round the globe.

3. A traveller proceeding from north to south finds the northern stars gradually disappearing below the horizon, and new stars gradually appearing in the south. In travelling from south to north these appearances are reversed, the southern stars being gradually lost, and the northern ones gradually appearing. Now, as this is just what would happen if the world were round; and as it could not possibly happen under any other circumstances, we may conclude from it that the world *is* round.

4. In making a canal, an allowance for curvature of about eight inches in the mile is needed, in order to maintain the water at the same level throughout. Were the earth a plane surface, this, of course, would not be necessary.

5 During eclipses of the moon, the boundary of the shade is always circular. Now, an eclipse of the moon is caused by the earth passing between the sun and the moon, and throwing its shadow upon the moon; and, as the earth is in different positions during different eclipses, it follows that the earth must be round, otherwise the shadow would assume different shapes.

6. When a triangle is carefully measured on the earth's surface, it is found that the sum of the three angles is greater than two right angles. This can *never* be the case on a plane surface, but must *always* be the case on a curved surface.

Exact Shape and how Determined.—We have now proved that the form of the earth is something like a ball, and we will proceed to show that the precise shape is that of an oblate spheroid, or such as might have been expected in the case of a rotating body which has cooled down from a molten state.

If we observe the height of the sun at mid-day at any place, or find its *meridian altitude*,[1] as it is called, and then travel southwards until its altitude is increased by a degree, it is evident that we shall have passed over one degree of the earth's surface. Now, if we measure this distance accurately, we shall obtain the length of a degree; and as we shall be

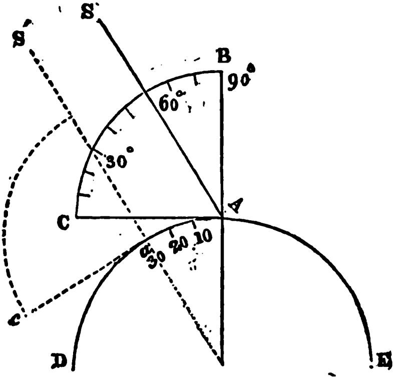

Fig. 1. Diagram showing the method of measuring degrees of the earth's surface.

In this figure the lines AS and *a* S′ are both supposed to be pointing in the direction of the sun, and would touch it if prolonged so far. Thirty degrees have been chosen instead of one, to prevent crowding the lines together. The reasoning is the same for one degree as for thirty.

---

[1] L., *meridianus*, pertaining to mid-day. L., *altus*, *altitudo*, height.

measuring a curved surface and not a plane, it will give us the amount of curvature at that place. It is found that everywhere these degrees are of nearly the same length, and that length is 364,578 English feet.

To render this more plain, let DAE (fig. 1) represent the outline of a portion of the earth, and let A be the station of the observer. Then B will be the direction of his *zenith*[1], AC the direction of his horizon. Let S be the direction of the sun, and suppose it to be 60° from the horizon, or 30° from the zenith, as shown by the scale attached to the curved line. Now suppose the observer to travel to *a*; here *ac* is the direction of the horizon, and S′ the direction of the zenith and of the sun also. In this case the sun's altitude is 90° (instead of 60° as before); it therefore seems to have ascended 30°, whereas the fact is, the observer has moved over 30° of the earth's surface in passing from A to *a*.

If the degrees were of the same length everywhere, the earth would be a sphere; but though very nearly, they are not precisely alike, but are found everywhere to become longer as we approach the poles. "An increase in the length of a degree indicates a less amount of curvature, the earth's surface is, therefore, less curved, that is, is flatter as we approach its poles from all sides from the equator" (*Herschel*). This conclusively proves the shape of the earth to be an oblate spheroid.

Annual Revolution.—Besides the diurnal rotation on its axis, the earth possesses another motion, namely, a motion round the sun. It would take us far away from our subject to describe how this was ascertained; we shall, therefore, describe it without entering upon any such details.

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[1] Sp., *zenit*, from Arabic, *semt-ar-ras*, the quarter (or direction) of the head.

The Planets.—The earth is one of a number of bodies which revolve about the sun as a centre. The paths in which they travel, or their *orbits*,[1] as they are called, are elliptical in shape, and in the case of the earth not much differing from a circle. These bodies are called *planets*, from the wandering course they describe in the heavens, which appearance is due to the revolution above mentioned, and to the difference in the speed with which the planets travel in different parts of their orbits. Of the planets there are eight principal ones, and an unknown number of smaller ones, of which there are at present 116 already discovered. The names of the eight principal planets are as follows, starting with the one nearest the sun:—

1. Mercury. 2. Venus. 3. Earth. 4. Mars.
5. Jupiter. 6. Saturn. 7. Uranus. 8. Neptune.

Of these the first four are called *interior* planets, the rest *exterior* planets.

The axis of the earth is not perpendicular to the plane of its orbit, but is inclined to it at an angle of 23° 28′.[2] Another very important point to remember is that, during the whole of its revolution round the sun, the axis remains parallel to itself; in other words, it points always to the same place in the heavens. The phenomena of *day* and *night* and the *seasons* are the result, *primarily*[3] of the revolution of the earth round the sun; *secondarily*,[4] of the inclination of the axis to the plane of the orbit, and of the parallelism of the axis. The earth revolves upon its axis rather more than 365 times in the course of one revolution round the sun. The period of one such revolution is called a *year*, and its exact length is 365 days 5 hours 48 minutes 51·6 seconds.

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[1] L., *orbita*, literally *the track made by a wheel*, a course.
[2] The signs °, ′, ″, mean, degree (°), minute (′), second (″).
[3] L., *primus*, first, in the first, or chief place.
[4] L., *secundus*, second, in the second, or subordinate place.

Day and Night: the Seasons.—We will now proceed to describe the phenomena of *day* and *night*, and of the *seasons*, by reference to the following diagram (fig. 2), in which the ellipse represents the orbit of the earth; A, B, C, D, the position of the earth at different periods; P, P, the north and south poles respectively; S, the position of the sun; and the arrows, the direction of the earth's motion. The shaded portion shows what part of the earth is not illuminated by the sun's rays; this is determined by a plane passing through the earth's centre, and perpendicular to a line joining the centres of the earth and sun; and the circle formed by the intersection of this plane with the surface of the

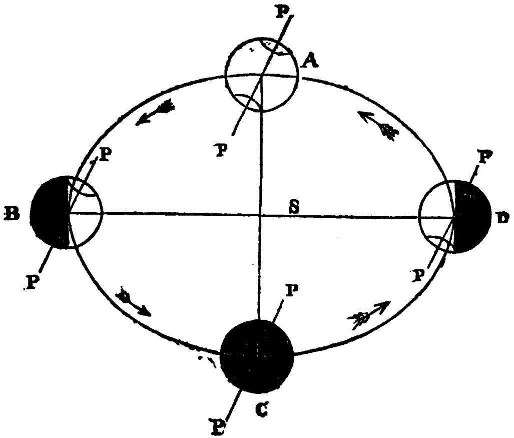

FIG. 2. DIAGRAM OF THE SEASONS.

earth is called the *circle of light and darkness*, or the *circle of illumination*, if light only be mentioned.

When the earth is in the position A, the circle of illumination passes through both the poles, and it is day over half the northern and half the southern hemisphere at the same time. As the earth revolves on its axis, every portion of the surface, therefore, is illuminated for twelve hours, and passes the other twelve in darkness, so that day and night are equal in length over the whole world. Hence this time is called the *equinox*.[1] As the earth is in such a position about March 21st, it is called the *vernal*,[2] or spring equinox, to distinguish it from the *autumnal* equinox, which happens about the 21st Sept., when the earth is at C.

As the earth travels in the direction from A to B, the north polar region is brought more and more within the circle of illumination, until when it reaches B, the north pole and all the region 23½° from it revolve in continual light. At the same time the south polar region has been carried further and further away from the light, and continual night reigns within the antarctic[3] circle. It is evident, therefore, that the days have been growing longer in the northern, and shorter in the southern hemisphere, during the progression of the earth from A to B. At the equator the length of day and night are still equal. Now, the longer the day the greater the amount of heat received from the sun, and the shorter the night the less will the earth cool down before the succeeding day brings renewed warmth; so that, while the days in the northern hemisphere have been growing longer, they have also been growing warmer; or, in other words, summer has been coming on. The earth arrives at B about June 21st, and this is called the *summer solstice.*[1]

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[1] L., *æquus*, equal, and *nox*, night. [2] L., *vernalis*, spring.

[3] L., *anti*, opposite, and Gr., *arktos*, a bear, referring to the northern constellation, the Great Bear.

Still moving in the same direction, the days in the northern hemisphere grow shorter, and therefore colder, until the position C is reached, when the circle of light and darkness again passes through the poles, and day and night are equal once more over all the earth. This occurs about September 21st, which is the time of the *autumnal equinox.* Day and night are still equal at the equator.

In travelling from C to D, the days in the northern hemisphere still continue to grow shorter and colder, until the *winter solstice* (D) is reached, about December 21st. The whole of the arctic circle revolves in darkness at this time, and the whole of the antarctic circle in light; while at the equator day and night remain equal.

The autumnal equinox, then, is the reverse of the vernal, and the summer the reverse of the winter solstice.

On the earth's journey towards A, the north pole is once more carried into light; the days, therefore, grow longer, and consequently warmer, and winter gives way to spring.

Briefly to recapitulate these points,—from the winter to the summer solstice the days in the northern hemisphere grow longer and warmer; while in the southern hemisphere they grow colder and shorter. From the summer to the winter solstice the northern days grow shorter and colder, and the southern days longer and warmer. The seasons are reversed in the two hemispheres, midsummer in the northern corresponding with mid-winter in the southern hemisphere, and *vice versâ.* The equator in astronomy is called the *equinoctial* line, because there the days and nights are equal all the year round, or in other words there is a perpetual equinox.

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[1] L., *sol*, the sun, and *sisto*, to make to stand. So called, because the sun seems to stand or linger in that position before moving back.

Nutation.—We have now shown how the varying lengths of day and night, and the succession of the seasons, are caused by the inclination of the earth's axis to the plane of its orbit, and the revolution of the earth around the sun. And it is easily seen that if the axis were perpendicular to the plane of the orbit, one unvarying equinox would reign over the globe, and the succession of seasons would be lost. Eternal winter would rule in polar regions, perpetual spring for ever weary the inhabitant of temperate climes, and the full blaze of summer always beat upon the torrid zone. If, then, this inclination should change, it would greatly modify the character of the seasons; and it does actually vary. The angle, as we have said, at present is 23° 28′, but it diminishes about 48″ in a century, and will go on diminishing for an immense period, after which it will increase again. In other words, the axis itself revolves in a small ellipse, and does not always point exactly to the same place in the heavens. Hence arises the *variation in the obliquity*[1] *of the ecliptic*[2]; for if the axis were perpendicular to the plane of the orbit, the ecliptic would then coincide with the equator, and the greater the inclination of the axis, the greater the obliquity of the ecliptic. This motion of the earth's axis is called *nutation*,[3] and is caused by the influence of the planets upon the earth. The diameter of the circle thus described is about 2° 42′, and its period of revolution about 270,000 years.

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[1] L., *obliquus*, slanting. [2] Gr., *ekleipsis*, a failure; literally, the line along which eclipses take place, or where light *fails*. The path which the sun appears to describe over the earth, in consequence of the revolution of the earth about the sun. [3] L., *nutans*, nodding.

Excentricity of the Earth's Orbit.—The attraction of the planets causes another disturbance in the earth's motion. We have said that the orbit of the earth is elliptical in shape, but that the *excentricity*[1] was so slight that the orbit was very nearly circular. Year by year the orbit is growing more and more circular, or the excentricity is growing less; and this will go on for 23,918 years, or till A.D. 25,780, when it will be as nearly circular as it can be. After this it will again increase for ages. Some 210,000 years ago the excentricity was nearly at its greatest, and since that time it has decreased slowly and *irregularly*. The irregularity with which this change takes places will be best understood by a few illustrations: 850,000 years ago the excentricity was greater than it had ever been for a million years; 900,000 years ago it was less than it had been for the same space of time; 800,000 years ago it had again diminished to very little; 750,000 years since it was again high, and then it decreased again; and though sometimes it was more than at others, it was comparatively low for 540,000 years, after which (210,000 years ago) it was again very high, and since then it has decreased irregularly and not very constantly, sometimes increasing for a period, and then dropping to a less excentricity than before.

Precession of the Equinoxes.—Another movement is that called the *precession*[2] *of the equinoxes*, which means that the equinoxes come round sooner than they otherwise would, or in other words they *precede* their time. As shown in the article on the seasons (p. 11), the earth makes one revolution about the sun from, say, the vernal equinox to the vernal equinox next succeeding. This, however, is not altogether true, for if the sun sets out from any fixed star at the moment of crossing the equinoctial line, it will cross the equinoctial again some twenty minutes before it arrives at the same fixed star, for the *equinoctial points*[1] go back westwards about 50″ in a year, and thus meet the sun. This *precession* is occasioned by the attraction of the sun and moon upon the bulging portion of the earth, for if the earth were a sphere there would be no precession. The effect of the precession of the equinoxes is that the seasons are brought about successively in every part of the earth's orbit, winter sometimes occurring where summer now happens, and so on. This movement by itself would cause the equinoctial points to perform the circle of the equator, and the seasons to coincide with each point of the orbit once in 25,868 years.

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[1] L., *ex*, out of, *centrum*, the centre. The excentricity of the orbit denotes the amount of deviation from a circle. [2] L., *pre*, before, and *cedo*, *cessum*, to go.

Revolution of the Apsides.—But this cycle[2] of changes is shortened by being combined with a motion caused by the attraction of the planets, called the *revolution of the apsides.*[3] The *apsides* are the points at which the earth is nearest to and farthest from the sun; a line connecting these points is called the *line of the apsides*, and it corresponds of course to the longer axis of the earth's orbit. Now this axis is not continually directed towards the same point in the heavens, but slowly revolves, and the result of the combination of this revolution with the precession causes the cycle of the seasons to be performed in about 21,000 years instead of 25,868 years.

In these varied movements we see a powerful cause of change in climate but the limits of so short a treatise forbid any enlargement upon this subject.

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[1] The *equinoctial points* are the points where the ecliptic crosses the equator or equinoctial line.

[2] Gr., *kyklos*, a circle. A cycle is an interval in which events re-occur in a certain order.

[3] Gr., *hapsis*, a curved form; sing., *apsis*.

Recapitulation of Movements. — The earth's movements are as follows :—

1. *Diurnal revolution* on its axis.
2. *Annual revolution* round the sun.
3. *Nutation*, a vibratory motion of the earth's axis, due to the disturbing influences of the nearer and larger planets.
4. *Variation in the excentricity of the orbit*, due to the same cause as the above.
5. *Revolution of the apsides*—a revolution of the axes of the orbit, also due to the same disturbing cause.
6. *Precession of the equinoxes*, by which a given equinox occurs twenty minutes earlier than it otherwise would, owing to the equinoctial points receding 50″ per annum; due to the influence of the sun and moon upon the excess of matter at the equator.

Size of the Earth.—The size of the earth has been estimated very carefully, and the most recent investigations give as its dimensions,

Polar diameter	7,899·2	miles
Equatorial diameter. . .	7,925·6	„
Difference, or Compression	26·4	„
Mean Circumference . .	24,857·5	„
Extent of Surface . . .	197·	million sq. miles
Cubic contents	256,000	„ cu. „
Weight	5,852	trillion tons.

Professor A. S. Herschel, in a letter to the author, says: "I recollect that my father mentioned to me a curious approximation to the length of an ellipse of small excentricity (like that of a terrestrial meridian AB ab, produced by a polar compression, BC bc, at each pole), that the whole length, AB ab, of the *ellipse* is less than that of the *circle* AC ac on its major axis as diameter, by *one whole circumference* of the small circle BC described on the polar compression at one of the poles (or difference between the equatorial and polar radii of the earth) as diameter. I have just verified, for my own satisfaction, this curious geometrical property; and found in addition that the *surface* of the earth's spheroid is equal to the curved surfaces of a cylinder touching the earth at the equator, and *shorter than the uncompressed* polar axis (or diameter of the equator) by ⅔ of the actual polar compression (or ⅔ × 26·47 = 17·65 miles).

"Taking the equatorial diameter = 7925·65, and the polar axis = 7899·17, I obtained the *spherical* (or uncompressed) surface of the earth = 197,340,350 square miles, and the *actual* compressed, or spheroidal surface = 196,900,880 square miles.

"For the volume of the earth, which is (equally for a spheroid or a sphere), ⅔ of the circumscribing cylinder I obtained $\frac{2}{3} \times (0·785398) \times (7925·65)^2 \times (7899·17) = 259{,}806$ million cubic miles, which agrees with the solid contents given in Sir John Herschel's work.

"The weight of the globe, on the supposition of its density being 5½ times that of pure water, 5852 trillions of tons, also agrees with this figure, if the weight of one cubic foot of pure water is 62·321 lbs., which it is almost exactly, at 62° F."

The density of the earth has been estimated in three ways; (1) by observing the attraction which a mountain exercises on a plumb-line, as compared with the earth's attraction upon it; (2) by comparing the attraction of large balls of known weight and density upon a freely suspended bar, with the attraction of the earth upon the balls; (3) by observing the vibrations of pendulums at, above, and below the surface, and calculating the effect of the increased and diminished distance from the earth's centre. The mean of these experiments gives the density as about 5½ times that of water—a density double that of the rocks forming the known crust of the earth.

Comparison of the Earth and Sun.—The earth is very small in comparison with the sun; its diameter being over a hundred times less than that of the sun, which is 848,077 miles. The *bulk* of the sun (which must not be confused with the mass) is about 1,250,000 times that of the earth, but its *mass*, that is, the actual quantity of matter composing it, is only about 320,000 times as much as the mass of the earth. In other words, the material of which the earth is composed is denser, or heavier, than that composing the sun, bulk for bulk.

Centrifugal Force.—In consequence of the earth's diurnal rotation, bodies upon its surface have a tendency to fly off, like drops of water from a top: this tendency is called *centrifugal*[1] force. The faster the earth revolves the greater is this tendency; and as the motion is greatest at the equator, where any spot has to sweep through 25,000 miles in twenty-four hours (or about 1000 miles an hour), while at the poles the motion is merely upon itself, so centrifugal force is most powerful at the equator. In other words, bodies there have a greater tendency to fly off or "go up in the air," than at any other place. If the earth revolved seventeen times faster than it does, the tendency to fly off would exactly equal the force of gravity of the earth, and bodies would have no weight. As it is, bodies weigh less at the equator by 1-100,569th than they would at the poles.

The Circles of the Globe. The circles[2] of the globe are (1) the equator, (2) the tropics, (3) the ecliptic, (4) the polar circles, (5) parallels of latitude, (6) terrestrial meridians, or meridians of longitude.

(1) *The Equator*[3] is a line drawn so as to divide the earth into two halves or *hemispheres.*[4] It is in every part *equidistant*[5] from the poles. From it latitude is measured, and is called *north* or *south* latitude, according as it is in the northern or southern hemisphere.

(2) *The Tropics*[6] are lines drawn 23½° north and south from the equator (or in 23½° north and south latitude) and parallel to it. The circle to the north of the equator is called the *tropic of Cancer;* that to the south, the *tropic of Capricorn.* They are called *tropics*

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[1] L., *centrum*, the centre, and *fugo*, to fly.

[2] Though called *circles*, many of them are ellipses owing to the earth's figure.

[3] L., *equator*, that which divides equally.

[4] Gr., *hemi*, half, and *sphaira*, a globe or sphere.

[5] L., *æquus*, equal, and *distant.*

[6] Gr., *trepo*, to turn.

because the sun in his apparent *annual*[1] course about the earth (due to the earth's travelling round the sun) seems to turn back again when perpendicular over that line. If the earth's axis were perpendicular to the plane of its orbit, there would be no tropics; as it is, they are situated exactly as far distant from the equator as the inclination of the earth's axis varies from the perpendicular, that is, 23° 28′ or nearly 23½°.

(3) *The Ecliptic*[2] is the line on the earth's surface along and perpendicular to which the sun appears to travel each year. It cuts the equator obliquely, and extends from tropic to tropic.

(4) *The Polar Circles* are described about the poles at the same distance as the tropics from the equator, that is 23½° nearly. The circle about the north pole is called the *Arctic Circle*,[3] that about the south pole the *Antarctic Circle*.[4] The circle of light and darkness lies always upon or within the polar circles. If the earth's axis were perpendicular to the plane of its orbit, there would be no polar circles; as it is, they are distant from the poles the same number of degrees as the earth's axis is inclined from the perpendicular.

(5) *Parallels of Latitude*[5] are circles drawn parallel to the equator, and at any number of degrees from it.

(6) *Terrestrial Meridians*,[6] or *Meridians of Longitude*[7] are circles drawn through the poles at right angles to the equator, and at any number of degrees from each other.

Latitude and Longitude.—The circumference of the earth is divided into 360 degrees (°), and as the poles are one quarter of the circumference, or 90°, distant from the equator, they are said to be in 90° north or south latitude, the equator being latitude 0°. A place half-way between the pole and the equator, is in 45° north or south latitude and so on. But as any place the same distance from the equator, say 45°, is in the same latitude, it may be anywhere on a circle or parallel drawn 45° from the equator. To find the position of such a place, it is necessary to find *whereabouts* on that parallel the place is situated. This is determined by means of the longitude; but in reckoning longitude, there is no position to start from, like the equator or the poles, as in the case of latitude, for one meridian does not differ from another. Hence a meridian passing through some well-known place is chosen, and is called 0°; and places are said to be in *east* or *west* longitude, according as they lie east or west of that meridian. The meridian chosen by English geographers is that passing through the Observatory of Greenwich; and to this we shall always refer in the following article. French geographers reckon their longitude east or west from Paris. If, then, the position of a place is said to be in latitude 45° north, and longitude 30° east, its position is easily found. We have only to draw a circle parallel to the equator and 45° north of it, and a meridian 30° east of the meridian passing through Greenwich; and the position of the place required, is where the two lines cross.

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[1] L., *annus*, a year, yearly. [2] [3] [4] See notes pp. 12 and 14 for derivation. [5] L., *latitudo*, breadth. [6] L., *terra*, the earth, *terrestris*, belonging to the earth, and meridian, see p. 8. [7] L., *longitudo*, length.

The greatest latitude a place can have, is 90°. The greatest longitude 180°; for if from 0°, we reckon 10°, 20°, 30°, and so on, east and west, the meridians will meet in 180° on the opposite side of the earth; the meridian 180° being the continuation of meridian 0°.

The Method of Finding the Latitude.—In order to understand how latitude is found, the student must bear in mind that the *celestial*[1] *pole* is the point in the heavens which the earth's axis would reach if prolonged, and round which the stars appear to revolve. The *celestial equator* is the circle in the heavens which corresponds to the terrestrial equator, or which would be described if the plane of the equator were prolonged so far. The distance from the celestial pole to the celestial equator, like the distance from the terrestrial pole to the terrestrial equator, is 90°. The point immediately overhead, is called the *zenith*.[1]

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[1] L., *celestis*, belonging to the heavens.

If the distance of the zenith from the celestial equator be measured, it, of course, gives in degrees the distance of the place of observation from the terrestrial equator, that is, the latitude. The zenith can easily be found, for it is the spot to which a *plumb-line*[2] points, but the celestial equator is not so easily ascertained. The distance of the zenith from the celestial pole will, however, be equally useful for the purpose, and the Pole-star enables it to be found readily in northern latitudes. Suppose this distance be 30°, then as the pole is 90° from the equator, we have only to take 30° from 90°, and the remainder 60° gives us the latitude of the place.

But the pole-star is not exactly at the pole, so that it would cause an error in the observation, if that star were used as if it were at the pole. If, however, we measure the distance of the zenith from some star, whose distance from the pole is known, we shall avoid this source of error. Say the distance is found to be 20°, and the known distance of the star from the true pole, be 10°, then we at once find the distance of the zenith from the pole, by adding 20° to 10°, that is 30°; this taken from 90° gives 60° for the latitude as before.

If the distance of any body, say the centre of the sun, from the celestial equator be known, the latitude can be readily ascertained. When the sun is on the meridian, that is at noon, we measure the distance of its centre from the zenith: suppose this to be 40°, then knowing the distance of the sun's centre from the equator on that day, say 20°; this added to 40°, gives the latitude 60°. The position of the sun and the principal stars from the equator, or their *declination*,[1] as it is called, is given in a work called the Nautical Almanac, which is published some years in advance.

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[1] See page 9 for meaning.

[2] L., *plumbum*, lead. A line with a weight, usually of *lead*, attached to it, and freely suspended.

The instrument used in these observations is called a *quadrant*,[2] consisting of a quarter of a circle marked into degrees, a plumb-line is attached to the instrument, and hangs parallel to one side of it when an observation is being taken, thus pointing to the zenith. A movable telescope is fixed upon the centre, and is directed towards the object whose distance from the zenith is to be found, and the angle formed by the telescope with the plumb-line, is the same as that between the object and the zenith.

At sea the plumb-line cannot be used, owing to the ship's motion; and observations are made with a *sextant*,[3] which measures the distance of an object from the horizon. Now the distance of the zenith from the horizon, is 90°; so that if we subtract the distance of the object from the horizon from 90°, it gives us the distance from the zenith, from which the latitude is at once determined.

The Method of Finding the Longitude.—This is a much more difficult problem than that of finding the latitude; for, in the present case, we have no such determinate positions as the pole and the equator to which to refer. We have instead to find the distance in degrees from a meridian which has nothing to distinguish it from any other meridian.

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[1] L., *de*, away from, and *clino*, to bend.

[2] L., *quadrans*, from *quatuor*, four.

[3] L., *sextans*, a sixth part; so called because it consists principally of a sixth part of a circle, or an arc of 60°.

Suppose it to be noon at any place, say Greenwich; the sun is at its greatest height in the heavens, and as the earth turns towards the east, the sun appears to sink towards the west. If it were possible to travel westwards just as fast as the earth moves eastward, it is evident that we should keep continually under the sun, or in perpetual noon-day, and in twenty-four hours[1] should have travelled right round the earth. It follows, then, that places east of Greenwich pass under the sun, or have noon earlier, and places westward later than at that place. On such a journey as the above we should have traversed one complete parallel of latitude, namely that of Greenwich. The whole circumference of the earth then (or 360) passes under the sun in twenty-four hours, and one 24th of 360°, or 15° in one hour. The difference in time at two places at the same moment gives us the number of degrees of longitude they are apart, a difference of one hour corresponding to a difference of 15° in longitude, or four minutes to one degree.

The *problem*[2] of finding the longitude resolves itself into discovering a mode of ascertaining what time it is at Greenwich when it is a certain time, say noon, at the place of observation. To find the time of day at the place of observation, it is only necessary to observe the moment when the sun crosses the meridian, and that is 12 o'clock, or noon. Or if this cannot be done, as at sea, the latitude is first determined, and then the altitude of the sun at any convenient time; and the "Nautical Almanac" shows at what hour in a certain latitude on a given day, the sun acquires the altitude thus found.

The most difficult task yet remains, namely, to find what time it is at Greenwich when it is a certain time at the place of observation. For this purpose very beautifully made clocks, called *chronometers*,[1] are used. These are set to exact Greenwich time, and being carried in the ship during the voyage, the time is at once seen by referring to the chronometer. But however carefully and beautifully made, chronometers are liable to error; and a more certain method of finding Greenwich time is by what is known as the *lunar method*, because the *moon* is most often observed for the purpose. The positions of the sun, the moon, and the planets, among the fixed stars is accurately known, and laid down in the wonderful book, the "Nautical Almanac," for every day and hour. From this book the navigator learns what is the exact Greenwich time for every position of those bodies; and when he has determined what is the position, by means of the sextant, he can with ease determine that time, and knowing the time where he is, or the *local*[2] time, he at once deduces his longitude.

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[1] More exactly in 23 h. 56 m., the period of one revolution.

[2] Gr., *problema*, to throw before, or to put forward; a question put forward.

There are many details which render the finding of latitude and longitude more complicated than is stated in the above sketch; but these have been omitted for the sake of clearness, and are unimportant to the student of physical geography.

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[1] Gr., *chronos*, time, and *metron*, a measure.

[2] L., *locus*, a place.

CHAPTER II.

THE LAND.

Definition.—That portion of the solid framework of the globe which is uncovered by water is called *land*. In this chapter we shall consider it merely as it affects the physical geography of the present surface, leaving its geological features, that is, the nature of the rock masses which form the land, for the subject of a future volume of this series.

Area and Distribution of Land.—Of the 197 millions of square miles that the surface of the earth contains, only about 52 millions are occupied by land. These 52 millions are thus distributed :—

Europe	3½	millions.
Asia, with Polynesia	21½	,,
Africa	12	,,
America	15	,,
Total . . .	52	millions.

The land is not distributed regularly and equably over the surface of the globe, but lies massed in the northern hemisphere, being found south of the equator only as the great peninsulas of South America and Southern Africa; and, as islands; some of these latter, however, as Australia and Madagascar, being very large. Europe, Asia, and Africa, from being known, at least in part, to the ancients, are called the *Old World*; North and South America, which were only discovered in 1492 by Columbus,[1] being named the *New World*. This is a very useful division; for the three continents composing the Old World are connected together, and form one great island, and the New World forms another, separated, however, from the other on the extreme east and west by only a few miles in Behring's Straits; the plants and animals of the two worlds, and many of their other features, are also very different.

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[1] The New World was visited by the Northmen before the time of Columbus. The name America is derived from Amerigo Vespucci, a Florentine navigator, who visited that continent with Hojeda, shortly after its discovery by Columbus.

The general distribution of the land is as follows:—

North of the Equator—Land .	39	million square miles.
„ „ „ Water .	59	„ „
South of the Equator—Land . .	13	million square miles.
„ „ „ Water .	86	„ „
Total . .	197	„ „

In the northern hemisphere the extent of water is half as large again as the extent of the land (or as 1½ : 1), and there is three times as much land as in the southern hemisphere. In the southern hemisphere the extent of the water is six-and-a-half times that of the land (or as 6½ : 1); and the water covers two-thirds more than in the opposite hemisphere.

In order to divide the globe into two hemispheres, so as to obtain the greatest amount of land in one, and the greatest amount of water in the other, a spot in the St. George's Channel, midway between Pembroke and Wexford must be taken as centre.[1] In this case the Land Hemisphere includes all Europe and Africa, nearly all Asia, and about two-thirds of South America; while the Water Hemisphere includes only Australia, the East India Islands, and the islands of Polynesia, the remainder of South America, the south polar land, and a very small portion of Asia. In the one hemisphere the land and sea are almost exactly equal (as 1 : 1·106); in the other there is very nearly eight times as much water as land (as 1 : 7·988). Only one-thirteenth of the dry land has land opposite to it in the other hemisphere, so irregular is the grouping.

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[1] London used to be considered as the centre of the Land Hemisphere; but, by the present arrangement, part of South America is transferred to the Land; and a corresponding portion of the China Sea is added to the Water Hemisphere.—*Lyell*, Prin. Geol. 10th Ed., vol. i., p. 257.

Configuration[1] (or shape) of the Land.—The great continent of Europe and Asia has it greatest breadth in an east and west direction; Africa and America, are longest from north to south. The great mountain chain in Europe and Asia, lies in the direction of the greatest length of the continent, that is east and west, and the same fact holds good for America, where the mountain range is from north to south; Africa has no such mountain axis. There is a tendency in all land masses to assume the form of pyramids, with their *vertices*[2] or points directed towards the south; this is seen strikingly in the form of both North and South America, Africa, India, Malacca, Kamtchatka, Greenland, etc., and on a smaller scale in Scandinavia, Spain, Italy, and Greece. Almost the only exceptions to this are Denmark, one or two peninsulas in Siberia, and Yucatan, in Central America, which point towards the north. Another peculiarity in these pyramids and peninsulas is that they generally terminate abruptly in a gigantic rugged cliff, which is often the termination of a mountain range: thus Greenland is terminated by Cape Farewell; America by Cape Horn, the last of the Andes; Africa by the Cape of Good Hope; India by Cape Comorin, the utmost limit of the Ghauts; and so on. Again, many of these peninsulas have islands at their termination: Greenland is an illustration of this, Italy has Sicily to the south, Greece the Archipelago, India has Ceylon, and other examples might be cited. It is worthy of remark that if the bed of the Atlantic were raised 2000 feet, a peninsula pointing south, and having an island as its extremity, would be formed between Africa and America.

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[1] L., *con*, together and *figuro*, to form.

[2] L., *verto*, to turn. The top or turning point of a triangle.

Another peculiarity in the general features of the land is the shape of the coast-lines on opposite sides of the same ocean, protuberances on one side corresponding with recesses on the other. This is remarkably the case with the Atlantic Ocean, where the irregularities in outline are so contrasted that if the New and Old Worlds were brought into contact they would fit like the pieces in a child's puzzle. In the case of the Pacific, this arrangement is not so striking, but is sufficiently so not to have afforded any obstacle to those philosophers who believed the land actually to have been so joined, and to have been forcibly torn asunder, and who have constructed maps showing "the earth before the separation." In many cases the general form of the continents may be traced to the action of the ocean currents; the Caribbean Sea and the Gulf of Mexico clearly owe their existence in some degree to the grinding effects of the equatorial current and the Gulf Stream. The Gulf of Guinea is probably due to the action of the South Atlantic and equatorial currents; the coast of South America on the west side is hollowed out by the Peruvian current; and other instances will easily be seen on reference to a good map showing the course of these currents.

Coast Lines.—The extent of the coast-line has a direct and most important influence on the commerce and, therefore, upon the civilisation of a country. Where the coast is varied in shape, hollowed out into bays or indented by great gulfs or rivers, a ready communication with the interior can be established;

but where it is simple in outline, and therefore of less extent, as in the case of Africa, the country is in a great degree closed to the influence of trade, and is left rude and uncivilised ages after more favoured districts have been opened up by the enterprise of commerce. The following table will show that Europe is the most favoured of all continents in this respect, North America comes next, then South America and Asia, and lastly Africa. In this table the first column gives the total length of the coast line, and the second shows the number of square miles of area to every mile of coast. The numbers given are taken from Herschel, Ansted, and Somerville; and, although differing among themselves, they all afford the same general result.

Continent.	*Coast-line.*	*Proportion of coast-line to area.*	*Authority.*
Europe.	20,000	1 in 170	Herschel.
	20,000	1 ,, 187	Ansted.
	17,000	1 ,, 164	Somerville.
Asia.	33,000	1 in 533	Herschel.
	36,000	1 ,, 528	Ansted.
	33,000	1 ,, 376	Somerville.
Africa.	16,500	1 in 420	Herschel.
	16,250	1 ,, 438	Ansted.
	16,000	1 ,, 530	Somerville.
N. America.	28,000	1 in 260	Herschel.
	28,000	1 ,, 266	Ansted.
S. America.	16,500	1 in 420	Herschel.
	16,000	1 ,, 440	Ansted.
N. & S. America.	31,000	1 in 359	Somerville.

This gives roughly an average of between 400 and 500 square miles of land to every mile of coast, for the entire surface of the globe.

Elevation.[1]—The mean elevation of a continent is the height above the sea that it would possess if the mountains and hills were levelled, and the valleys filled up, so at to reduce the whole to one even surface. In this supposed operation the mass of the mountains, stupendous as it may at first sight seem, really counts for but very little; for the grandest mountain chain, spread over the continent in which it stands, would raise the general level only by a few feet. The Alps, spread equally over Europe, would raise the general level only 21 feet (*Humboldt*); the Asiatic mountains would raise Asia 150 feet, according to Professor Ansted. The following table shows the mean elevation of the different continents, all of them estimated by Humboldt, with the exception of Africa, which is the work of Herschel.

Continent—	**Europe** . . .	. *Mean Elevation*—		**1342 feet.**
,,	**Asia**	,,	,,	**2264** ,,
,,	**Africa**	,,	,,	**1820** ,,
,,	**N. America** . .	,,	,,	**1496** ,,
,,	**S. America** . .	,,	,,	**2302** ,,

Slopes of Continents.—Mountain chains never slope equally on both sides, the gentler slope being directed towards the longest slope of the country in which they are situate. Thus the Asiatic mountains generally present steep faces towards the south, and gentler descents towards the north; the American mountains are steepest on the western side of the chains, and fall much less abruptly on the east. The chief slope of the Old World is towards the north; in the New World it is towards the east. The following table

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[1] **L., *e*, up, and *levo*, to raise. The height.**

(abridged from Hughes' "Outlines") gives roughly the lengths of the longer and shorter slope.

Eastern Asia	*N. Slope*	2,600	*S. Slope*	400
Western Asia	"	900	"	80
Central Europe.	"	450	"	100
Africa.	"	3,300	"	600
North America	*E. Slope*	1,600	*W. Slope*	800
Central America	"	2,000	"	300
South America	"	1,850	"	50

A. MOUNTAINS.

Mountains very seldom occur singly; their most usual arrangement is in *ranges* or *chains*, or, less frequently, in groups or *knots*. Their slopes are much less than is usually supposed, there being no case known of a mountain being anything like "perpendicular;" still less do they approach to the "overhanging" character so often described by travellers. "In the whole range of the Alps there is not a single rock which has 1600 feet of perpendicular height, or a vertical slope of 90°. The declivity of Mont Blanc towards the Allée Blanche, precipitous as it appears to be, does not amount to 45°; and the mean inclination of the Peak of Teneriffe, according to Humboldt, is only 12° 30′. The Silla of Caraccas, which rises precipitously from the Caribbean Sea, at an angle of 53° 28′, to the height of between 6000 and 7000 feet, is a majestic instance of, perhaps the nearest approach to verticality of any great height yet known."—*Mrs. Somerville.*

When mountains attain to more than a certain elevation, which varies with the latitude, their summits are clothed with everlasting snow; the lowest limit at which the snow remains unmelted through the year is called the *snow-line*. This, and the effects of mountains in modifying climate, and the peculiar distribution of life upon them, are treated of in subsequent chapters.

Mountain Systems.—Any chain or group of mountains with its offshoots is called a *mountain system;* thus we speak of the mountain system of the Alps or of the Andes; and in some cases the name of a country is given, and we speak of the mountain systems of Europe or of Italy.

There are only two great mountain systems in the world,—(1) That in the Old World which runs from the East Cape in Siberia, west-south-west across Asia to Spain and Marocco, a distance of 9000 miles; and (2) That which runs parallel with the west coast of America from within the Arctic Circle to Cape Horn, a distance of 10,000 miles. With the exception of the African and Australian ranges, all other mountain chains are offshoots from one or other of the above systems.

1. Old World System.—(*a*) ASIA. The great mountain system of the Old World commences on the shores of Behring's Straits at the East Cape; and running at first almost due west, and then suddenly bending southward, about the 160th meridian, sends a branch into Kamtschatka. The main chain gradually bends again westward, and continues its course through Siberia as the *Aldan Mountains*, sending a branch northward about long. 140°, and another southwards in long. 130°, which bends round Manchouria, clinging to the coast. The whole of this great region is almost unknown to travellers, and it is only when we get further west that we enter a region somewhat better known to Europeans. This western continuation is the great range of the *Altai Mountains*, which varies in breadth from 400 to 1000 miles, and nowhere appears to attain to more than about 10,000 feet in altitude, a height very inconsiderable as compared with its great length. Rising on the banks of the

Irtish, this range may be considered as the principal axis, and the mountains above described its eastern continuation, being known by different names—*Aldan*, *Yabloni*, etc.,—in different portions of its length.

Roughly parallel, and to some extent dependent upon the Altai Range, are three ranges; namely, (1) The *Thian-shan*, which lies north of the great desert of *Gobi* or *Scha-mo*. (2) The *Kuen-lin*, which forms the southern boundary of the above desert; and (3) The *Himalaya*, the highest range in the world, separating Hindostan from Thibet. The highest peak, *Gaurisauker*, or *Mount Everest*, is 29,002 feet above the level of the sea (more than 5½ miles). This range is some 2800 miles long, and is divided into three parts, called the "outer," the "inner," and the "trans" Himalaya. The central portion, or mid-Himalaya, contains the loftiest peaks, and its average height is about 16,000 feet, or about that of *Mont Blanc*, the highest European mountain; and there are said to be forty peaks whose altitudes are greater than that of the mightiest of the Andes in South America.

The Himalayas are joined on the west to the *Hindoo Cooch*, or *Koosh* mountains, which traverse the north of Afghanistan and Persia. The highest peak is over 20,000 feet above the sea. Still continuing westward, the Hindoo Koosh runs into the mountains of *Elbruz*, whose highest point is *Demavend*, (21,500 feet), and bending round Armenia, is prolonged into the *Anti-Taurus* range, which, with the *Caucasus* to the north, and the *Taurus* to the south, connect the mountain system of Asia with that of Europe.

The *Taurus* and *Anti-Taurus* ranges both start from near *Mount Argæus* in Armenia, 13,197 feet in height. The southern, or *Taurus* proper, runs first southward, then westerly to the coast of the Mediterranean. The northern, or *Anti-Taurus* range, skirts the table-land of Asia Minor on the north, and is continued into the *Balkan* mountains of Europe.

The *Caucasus* forms the boundary of Asia and Europe, between the Black Sea and the Caspian, a distance of 700 miles. Its highest point is Mount *Elbruz*, in Georgia, which is 18,526 feet. Besides this peak, several others attain to a higher elevation than the Alps; *Koschtantan* being 17,096 feet high; *Dychtan*, 16,925 feet; *Kasbek*, 16,546; and several others exceed 16,000 feet in altitude.

We have thus traced the great mountain system across the continent of Asia to its junction with, or rather continuation into, the European system. The higher mountains throughout the range have their summits buried beneath eternal snow, and give rise to glaciers, as will be described further on.

Several minor ranges exist in Asia which have not been noticed above. The principal are those of Arabia, Hindostan, and Further India.

Commencing in Syria, a range of mountains runs southward to the Gulf of Suez, and then keeps parallel with the Red Sea coast through its entire length. It is of no great elevation; the highest points being *Mount Hermon*, *Mount Sinai*, and *Horeb*, which are respectively 9376, 7413, and 8593 feet. The small range of *Lebanon* attains the height of 10,050 feet in *Dahr-el-Khotib*.

The secondary ranges of Hindostan are three in number—(1) The *Eastern Ghauts;* (2) the *Western Ghauts;* (3) the *Vindyha Mountains*. The *Ghauts* run parallel to the coast, and have a mean elevation of from 3000 to 4000 feet; some few points in the Western Ghauts being as much as 8000 feet. The *Vindyha* range lies to the north of the Deccan, and runs in an east-north-east direction. Its average height is about 3000 feet.

Birmah, Siam, Malaya contain ranges of mountains which seem to be branches from the Himalayan and Chinese ranges. The chief range is on the west side, and is known by the name of the *Aracan Moun-*

tains; it reaches the height of 6000 feet. The mountains of Siam, which though not very high are still bold, are connected with the Aracan range: their height may be taken at from 5000 to 6000 feet.

None of these secondary ranges are sufficiently high to reach the snow-line.

(*b*) EUROPE.—The mountain system of Europe is connected with that of Asia by the ranges of the Caucasus and the Taurus; the former connecting itself with the *Carpathian*, the latter more directly with the *Balkan* mountains.

The western portion of the *Carpathian* chain, near the mouth of the river Danube, is called the *Transylvanian* range, and is much lower than the true *Carpathians*, which form a kind of loop round Hungary. This main range is peculiar in having some of its higest peaks grouped upon one enormous mountain, *Mount Tatra*, which is 50 miles long in an east and west direction, and 30 miles broad from north to south. Its average height is about 7000 feet; its highest point is 8524 feet. Besides these the *Csalic Peak* rises to 8314 feet, and the *Lomnizt Peak* to 8799 feet. The highest point of the range does not, however, belong to this remarkable group, which is situated in the west, but lies in the Eastern Carpathians; it reaches the elevation of 9912 feet, and is called *Ruska Joyana.*

The *Balkan* range is connected with the *Carpathians*, lying towards the north, by a series of mountain ridges, which are cleft by the river Danube; the ravine or gorge so formed is called the *Iron Gate.* Three chains of mountains go to form the Balkan; two of them have a south-easterly direction towards Constantinople, while the third takes a more southerly route, and is prolonged through Greece as the *Pindus.* A characteristic feature of the Balkan is its being broken by numerous fissures or ravines extremely deep and narrow, whose gloomy beds form the best roads of the country. The highest point is *Mount Guiona*, in Greece, 8239 feet; *Mount Parnassus* is 8068 feet.

The term *Alps*[1] is applied not merely to that particular range which, commencing in Italy near the Gulf of Genoa, runs through Switzerland and terminates in the Tyrol, comprising within its course the highest mountains of Europe; but also to a number of other chains branching off in various directions, the Balkan itself being sometimes called the Eastern Alps. The western continuation of the Balkan is by the *Dinaric Alps*, reaching, in *Mount Dinara*, the height of 5670 feet; and passing through Dalmatia it receives the names of *Julian Alps*, terminating in *Mount Terglon*, 9343 feet in height; thence, to its junction with the main chain of the *Higher Alps*, it is known as the *Carnic Alps*, *Dreiherren Spitz*, 10,122 feet, being the highest point. The *Great Glockner*, 12,957 feet, is the point where the *Higher*, the *Carnic* and the *Noric* Alps meet. These last form a continuation of the Higher Alps, and run in the direction of Vienna. None of these secondary branches of the Alps are covered with snow the whole year round.

It is to the *Higher Alps* that the term *Alps* is usually applied. Commencing at Cape Delle Melle on the Gulf of Genoa, it runs in a north-westerly direction towards *Mount Blanc*, and then turning east-north-east terminates in the Great Glockner (*Grossglockner*), after a circuit of some 420 miles. This range is very lofty throughout the whole of its extent; but the principal peaks are situated in a district only about sixty miles in length, which contains *Mont Blanc*, 15,784 feet; *Monte Rosa*,

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[1] Said to be so named from the numerous feeding grounds, or *alps*, they contain. *Alp* is, however, the Gaelic for a mountain.

15,217 feet; *Mont Cervin*, or the *Matterhorn*, 14,705; *Grand Combin*, 14,164 feet, and many other extremely high mountains. Much of this range is above the snow-line.[1] An important branch, called the *Maritime Alps*, runs along the Mediterranean coast joining the *Apennines*, which traverse Italy from north to south, and are also an offshoot from the Alps. In the province of Calabria the chain splits into two branches, one ending on the Gulf of Taranto, the other continued to the extreme south of the peninsula and across the Straits of Messina into Sicily. The total length is about 800 miles. The highest point is *Monte Corno*, 10,206 feet, near the middle of the chain. None of the peaks reach the snow-line.[2]

The westerly extension of the Carpathians is by the *Sudetes*, which rise from near the river Oder, and run round Bohemia for 300 miles. The *Hyrcanian* mountains are a more important range, and start from the confines of Bohemia and Bavaria, running through central Germany to the river Rhine. The highest points of the range reach some 5000 feet above the sea.

The *Pyrenees* form the south-western termination in Europe of the great system of the Old World. They are separated from the Alps by the Plain of Languedoc, and stretch from the Mediterranean to the Bay of Biscay, a distance of 240 miles. They are very precipitous, especially on the French side; and their summits are clothed with perpetual snow, feeding numerous glaciers, which, however, fall far short of those of the Alps in point of size. The mean height is about 7000 feet, and its loftiest point is the *Maladetta*, or *Nethou*, 11,170 feet above the sea. Spurs or branches shoot off from the main range as far the river Ebro.

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[1] Other portions are known as the Leopontine, Cottian, Bernese, Graian, Pennine, Rhetian, Helvetian, and Julian Alps.

[2] Etna, in Sicily, only excepted.

Detached Mountain Ranges of Europe.—There are several detached ranges of mountains in Europe, the principal of which are the (1) *Ural*, the (2) *Scandinavian* and *British*, the (3) *French*, and the (4) *Spanish* mountains,

(1) The *Ural Mountains* form the boundary between Europe and Asia on the east, and extend more or less from the Sea of Aral to the Polar Sea; but south of the river Ural the elevation is so slight as scarcely to merit the name of mountain. Even the central portions slope so gently that they appear to be little more than undulations in the plain. To the north they assume a more mountainous character, rising to from 6000 to 7000 feet.

(2) The *Scandinavian Mountains* run through Norway and Sweden, from north to south, a distance of 900 miles. They consist of the *Norrska Fjellen* (*Norwegian range*) and the *Kjölen*. The latter lies to the north, and is about 500 miles long, and though not so elevated generally as the Norrska Fjellen, rises to 6200 feet in *Sulitelma*. The former lying to the south, is about 400 miles in length, and contains the highest points in the group, a huge mountain, the *Dovre Fjeld*, forms a great *plateau*,[1] out of which *Sneehätten*, 7620 feet high, rises, the highest in the chain.

The mountains of Orkney, Shetland, and Scotland, seem to form the southern continuation of the Scandinavian system. The highest mountain is *Ben Nevis*,[2] 4406 feet; then *Ben Mac Dhui*, 4296 feet; and *Cairntoul*, in Aberdeenshire, 4285 feet; no other mountain in the British Islands reaches the elevation of 4000 feet. The Scotch mountains are continued into England by the Pennine chain, the highest mountain being *Helvellyn*, 3313 feet; *Skiddaw* reaches 3038 feet The mountains of Wales attain the elevation of 3000 feet in several peaks; *Snowdon*, the highest, is 3590 feet; *Carn Llewellyn*, 3471 feet. The highest mountains of Ireland are in the south-west, in County Kerry, where *Carran Tual* forms the highest peak, being 3412 feet high.

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[1] French, *plateau*, literally, a large flat dish. A plain, applied only to elevated plains or *table-lands*.

[2] Ben Cruachan, in Argyllshire, is said by some to be nearly 5000 feet.

(3) *French Mountains.*—The principal detached mountains of France are the *Auvergne* mountains, a fine group of extinct[1] volcanoes rising to over 6000 feet; and the *Cevennes*, lying more to the east, and stretching to the river Rhone. They are not so high as the mountains of Auvergne.

(4) *Spanish Mountains.*—Spain is remarkable from possessing several detached mountain-chains, which, though not of great length, attain very considerable elevations. From their peculiarly jagged and saw-like appearance, they are called "*Sierras*," from a Spanish word, meaning a saw. The *Sierra Nevada* is the principal chain; the highest peak is *Mulahaçen*, 11,423 feet. The *Sierra Morena* runs parallel with the Nevada chain, but lies further north. The *Sierra Estrella* reaches over 7000 feet in altitude, and, with several other chains, lies between the Sierra Nevada and the Pyrenees.

(c) AFRICA.—There is in the continent of Africa no system of mountains trending in a given direction, such as we find in Asia and Europe; but the mountain system of the north is important, as forming a part of the great Old World system, described as running in a south-westerly direction, and thus connecting itself with the other two continents.

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[1] Latin, *ex*, out, *stinctus*, quenched, or dead; here used to distinguish from *active* volcanoes.

The *Atlas* range stretches from Tunis, on the Mediterranean, to Cape Geer, on the Atlantic. The general trend is from east-north-east to west-south-west, or the same as the other portion of the Old World system. It is somewhat vaguely divided into three portions, called the *Greater*, the *Lesser*, and the *Middle* Atlas. The *Greater Atlas* lies furthest inland; and, as its name implies, is the main portion of the range. Its loftiest peak, *Mount Atlas*, in Marocco, is 11,400 feet. A branch of the *Lesser Atlas* runs out to Ceuta, opposite Gibraltar, thus connecting the Atlas group with the mountains of Spain.

A more or less connected range of mountains runs roughly parallel with the east coast of Africa, sending up peaks 10,000 feet high. These mountains are connected with those of Abyssinia and Nubia, which attain in the former country to an elevation of 15,000 feet; *Abba Jarrat* being 15,088 feet.

Along the west coast a series of mountain ranges occur, commencing in Senegambia, and reaching almost to the Tropic of Capricorn. It is not certain whether they belong to one continuous range. They rise occasionally to great heights, and form in all cases fine bold scenery. Their highest peaks aro estimated at about 13,000 feet.

Recent discoveries have determined the existence of at least one great range running across Central Africa, and rising above the snow-line. It seems to be connected with the mountains of Abyssinia, and, perhaps, also with those of the west coast. The highest point, at all satisfactorily made out, is *Kili-man-jaro*, partly ascended by Von Decken, and by him estimated at 20,000 feet.

From the Cape of Good Hope eastwards to the river Zambesi, a range of bold mountains runs.

Like so many of the African ranges (as the Abyssinian and Equatorial mountains), they are cleft and torn by ravines, often extremely long, narrow, and deep. Westwards the range is continued to the Orange River, but not on so grand a scale; eastwards it runs towards and may join the East African range.

2. **New World System.**—The mountain system of the New World is far simpler than that just described. It consists of one majestic range following the Pacific coast-line from the Arctic to the Antarctic Ocean, a length something under 10,000 miles. Though continuous, this great chain falls naturally into three divisions, each possessing its own peculiarities, the *Rocky Mountains*, the *Mexican Andes* in Central America, and the *Cordillera of the Andes*, in the south. "Though simple in its main features, it is complex in its details, consisting of two or more chief axes. Towards the north these are rather widely separated, and only at a few points do the ridges culminate to peaks above 10,000 feet in height. In the central part there are very extensive, lofty plateaux, not always bounded on both sides by mountains. The southern division . . . is double throughout, and projects spurs to the east."—(*Ansted.*)

(*a*) NORTH AMERICA.—Rising from the Arctic Ocean as a range of but slight elevation, the *Rocky Mountains* gradually increase in size towards the south; and about latitude 52° reach the height of 15,000 feet in *Mount Hooker*, 15,789 feet in *Mount Murchison*, and 16,000 feet in *Mount Brown*. A chain runs parallel to the main ridge some distance to the east; but in latitude 42° the two chains are united by a knot, called the *Snowy Mountains*. The most important of the secondary chains runs close to the coast, and in it is found the highest mountain in

North America, *Mount Elias*, 17,850 feet. It lies at the extreme north of the range. The Rocky Mountains end at the Rio del Norte, in latitude 29°.

(*b*) CENTRAL AMERICA.—The *Mexican Andes* are not quite continuous with the Rocky Mountains, but do not differ in any important feature from them. There are two ridges, of no great height, seldom exceeding 2000 feet, and inclosing the great plain of Mexico. South of this, in Central America proper, the mountains are much loftier, rising to 10,000 feet, and are continued into South America.

(*c*) SOUTH AMERICA.—The *Cordillera of the Andes* has been thus divided :—

1. **Andes of New Granada**	Northern Andes.
2. „ „ **Ecuador**	
3. **Peruvian Andes**	Central Andes.
4. **Bolivian** „	
5. **Chilian** „	Southern Andes.
6. **Patagonian Mountains**	

Generally speaking, the Andes consist of a double or treble chain, of which that nearest the coast is the highest. They are extremely lofty throughout, and rising so directly from the sea, are really the largest mountains in the world. The Himalayas reach a greater elevation, it is true, but they rise not from the sea, but from an elevated table-land. The greatest elevation is attained in Peru and Bolivia, where many peaks rise to over 20,000 feet; in New Granada and Chili many summits are found over 16,000 feet. In Patagonia the range runs for a thousand miles close to the coast; and rapidly diminishing in altitude, till the mean height is not much above 6000 feet, they at length terminate abruptly in Cape Horn at the utmost extremity of South America. The Andes form a grand centre of volcanic action, many of the highest peaks being active volcanoes.

Detached Ranges.—The chief secondary range of North America is that of the *Alleghany* or *Appalachian Mountains*, which run parallel with the Atlantic coast. It consists of two or three parallel ridges, which, commencing in Alabama in the south, are continued right through the States to the banks of the St. Lawrence, taking various names in different parts. The range is not lofty, averaging about 3000 feet, but rising to 6,400 in North Carolina and New Hampshire.

Two ranges occur in Brazil, running parallel with the coast, as in North America. The *Sierra do Mar*, or "coast mountains," are nowhere distant more than twenty miles from the ocean; and from their picturesque shape, and the richness of the vegetation with which they are clothed, produce scenery of the most lovely and varied description. The more inland chain, that of *Espinhaço*, attains a greater height than the coast-range. *Itambe* in this range, 8426 feet, is the highest mountain in Brazil. The *Sierra dos Vertentes*, runs across the country from east to west, reaching no greater elevation than 3,500 feet above the sea. It is singular as forming, with the mountains on the coast of Venezuela and Parima, the only exception to the meridional direction of the mountain chains in America.

The following table may be useful in showing the relation of the highest peaks in America.

NORTH AMERICA.

Rocky Mountains.

	Position.	Height in ft.
Mount St. Elias .	lat. 60° 20′; in coast range	17,850
Mount Fairweather	lat. 59° 2′; do.	14,788
Mount Brown . .	lat. 52°, in Rocky Mountains	16,000
Mount Hooker . .	Do. do.	15,700
Mount Whitney .	Snowy Mountains	15,000

Alleghanies.

Mount Washington	New Hampshire	6,428
Otter Peak	Virginia	4,266

CENTRAL AMERICA, with MEXICO.

Popocatapetl (*v*)	Mexico; lat. 18°	17,717
Orizaba (*v*)	Do.; lat. 19°	17,374
Fuego (*v*)	Guatemala	13,930
Irasu (*v*)	Costa Rica	11,480

SOUTH AMERICA.

Andes.

Tolima (*v*)	New Granada	18,020
Cotopaxi (*v*)	Ecuador	18,755
Cayambe	Do.	19,535
Chimborazo	Do.	21,424
Ancohuma	Bolivia	24,286
Illimani	Do.	24,200
Aconcagua	Chili	23,910?
Mount Stokes	Patagonia	6,400
Mount Sarmiento	Tierra del Fuego	6,900

Brazilian Mountains.

Itambe	Brazil	8,426?
Itacolumi	lat. 20° S.	5,710

Mountains marked (*v*) are Volcanoes.

3. **Australia and New Zealand.** The only important chain of mountains in Australia, runs parallel with the east coast. It is of an extremely rugged character, the spurs being described as "terrific," and the gullies which separate them as "dark and almost subterraneous," making the range an impassable barrier. It does not, however, attain any great height; averaging only some 3,000 feet. *Mount Kosciusko*, the highest point, is 7285 feet high. The range is called by different names in various parts, the chief being the Blue Mountains, in which *Mount*

Kosciusko is situated. In New Zealand, there is a lofty range parallel with the Australian mountains above described, rising in North Island to nearly 10,000 feet; but reaching its greatest elevation in South Island, where *Mount Cook* stands 13,200 feet above the sea, and *Mount Tyndall* 11,000. The summits of these mountains are buried in eternal snow, and give rise to large glaciers; numerous volcanoes also occur in this range, which is known as the *Southern Alps*.

(4) **Isolated[1] Mountains.** Under this head may be classed such mountains as are entirely disconnected from any of the great ranges. They are necessarily situated upon oceanic islands, except, perhaps, *Mounts Erebus* and *Terror*, terrific piles of rock, which, rising to 12,367 and 13,884 feet respectively, illuminate with hideous light the grim solitudes of the ice-bound Antarctic Continent. In the Sandwich Islands, in Hawaii, the twin-volcanoes of *Mauna Kea* and *Mauna Loa* frown upon the trembling sea, from the stupendous heights of 13,953 and 13,700 feet. The island groups off the West Coast of Africa are mountainous; but they belong to the system of that continent. The highest is the *Peak of Teneriffe* 12,205 feet high.

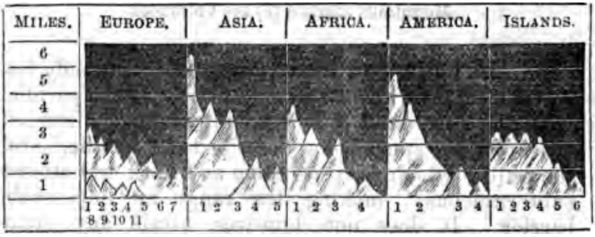

FIG. 3. DIAGRAM OF CHIEF MOUNTAINS.

The above diagram shows the relative heights of a few of the principal mountain peaks. The horizontal lines mark altitudes of one mile each. The mountains represented are:—

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[1] It., *isola*, an island. By itself; detached, like an island.

EUROPE.

1.	**Mont Blanc**	in the Alps.
2.	**Pic de Nethou**	,, the Pyrenees.
3.	**Etna**	,, Sicily.
4.	**Monte Corno**	,, the Apennines.
5.	**Ruska Joyana**	,, the Carpathians.
6.	**Guiona**	,, Greece.
7.	**Imesfjeld**	,, Norway.
8.	**Ben Nevis**	,, Scotland.
9.	**Snowdon**	,, Wales.
10.	**Helvellyn**	,, England.
11.	**Carran Tual**	,, Ireland.

ASIA.

1.	**Gaurisauker**	in the Himalayas.
2.	**Demavend**	,, Persia.
3.	**Elbruz.**	,, the Caucasus.
4.	**Dahr-el-Khotib**	,, Lebanon.
5.	**Sinai**	,, Arabia.

AFRICA.

1.	**Kilmandjaro**	in Equatorial Africa.
2.	**Abba Jarat**	,, Abyssinia.
3.	**Mount Atlas**	,, Marvuo.
4.	**Table Mountain**	,, Cape of Good Hope.

AMERICA.

1.	**Illimani**	in New Granada.
2.	**Cothopaxi**	,, Ecuador.
3.	**Mount St. Elias**	,, Rocky Mountains.
4.	**Mount Fairweather**	,, Rocky Mountains.

ISLANDS.

1.	**Mauna Kea**	in Sandwich Isles.
2.	**Terror**	,, Antarctic Lands.
3.	**Mount Cook**	,, New Zealand.
4.	**Teneriffe**	,, Canary Isles.
5.	**Mount Wellington**	,, Australia.
6.	**Ben Lomond**	,, Tasmania.

B. PLAINS.

Plains are generally considered to be of two kinds: (1) *Elevated Plains*, and (2) *Low Plains;* the former are also known as *Plateaux*[1] or Table-lands. There is no essential difference between the two; the fact of their occurring at different elevations being purely accidental, and not causing any difference in their character, except so far as climate is concerned. The peculiar features of plains depend upon their geological character, the latitude in which they occur, and their relation to the mountain-chains. Generally speaking, plains are the most fertile portions of a country, but they may also be arid sandy deserts; all that is necessary to constitute a plain being a more or less level tract of land. In different parts of the world the plains receive various names, under which they will be considered further on.

1. **Plateaux or Table-lands.** (*a*) EUROPE.—The plateaux of Europe do not constitute a very important feature of the continent. The largest lies in the east, and separates the low-plains of Central from those of Northern Russia. Its length is about 1500 miles, and its breadth varies from 50 to 200 miles. The *Carpathian plateau*, lying to the south of the above, is much smaller in size. It is situated between the great German (low) plain and the steppes of Russia.

The plateaux of Spain, though not so large, lie at greater elevations than those of north-eastern Europe, ranging from 2000 to 3000 feet above the sea. The central plateau is flanked by mountains on all sides, and the ranges of the Sierras Nevada, Morena, Guadarama, rise out of it, and break the general level. This plateau extends into Portugal, and contains 100,000 square miles of area.

France possesses some small plateaux, both in the north and in the south; but they are irregular in outline and elevation, and moderate in extent and altitude.

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[1] French, *plateau*, plural *plateaux*, a large flat dish, a table-land.

(*b*) ASIA.—It is in Asia that we find the grandest plateaux—grand alike in elevation and extent, stretching from the Mediterranean to the Pacific, maintaining over thousands of square miles an elevation greater than the average height of the Alps.

In the west the table-lands of Arabia and Persia cover an area of 4,000,000 square miles, varying from 3000 to 7000 feet above the sea. Then come the plateaux of Armenia; and so going east, right up to the Hindoo Koosh, one continuous stretch of desert table-land forms the western portion of the great Asiatic plateau.

East of the Hindoo Koosh and the Solimaun range we enter upon the eastern portion of the great plateau, which reaches its greatest height in Tibet, where it lies from 15,000 to 17,000 feet above the sea. The central portion is much less elevated, being only from 4000 to 6000 feet high. In this region lie the vast deserts of *Gobi*, *Scha-mo*, *Scha-ho*, and *Hanai*, to the north of Tibet, running in a north-north-east direction through Mongolia, almost to the Pacific Ocean. Several high ranges of mountains rise out of this plateau, the chief being the *Kuen-lun*. The Himalayas may also be considered as belonging to the plateau, rather than as a distinct range like the Thian-shan mountains; for they rise directly from it on the north, and descend into its continuation, the plateau of Northern India, on the south.

(*c*) AFRICA.—A great table-land extends from Abyssinia and Senegambia southwards to the extremity of the continent. It is not of very great elevation, being in its northern portions some 3000 to 4000 feet above the sea. Upon this table-land, close to the equator, are situated the great lakes known as the *Albert* and *Victoria N'yanzas*, which give rise to the White Nile, and Lake *Tanganyika*, discovered by Dr. Livingstone.

(*d*) NORTH AMERICA.—The chief plateau of North America is called the *Great Basin*, and, lying between the parallel ranges of the Sierra Nevada and the Rocky Mountains, extends from Mexico and California to what was till lately Russian America. Its mean elevation is estimated at 6000 feet, and it is mostly volcanic, with many salt lakes. The length is about 2000 miles, while the breadth in no case exceeds 600 miles. In the north and north-east, plateaux of no great elevation occur; and on the eastern slope of the Rocky Mountains a succession of slightly elevated plains slope down to the Mississippi.

(*e*) CENTRAL AMERICA contains the great plateau of Mexico or Anahuac, and the important but less extensive table-lands of Guatemala and Honduras. The Mexican table-land is bounded by mountains, and ranges also rise from its surface; but where not thus interrupted, the surface is perfectly level, so that "a carriage road of more than a thousand miles northward from the city of Mexico is either over a dead level or gentle undulations." Here we find the greatest known extent of uninterrupted table-land, a distance of over 1600 miles of almost dead level. Its elevation is comparatively small, ranging from 3000 to 7000 feet above the sea.

The plateau of Guatemala is 5000 feet above the sea. It is well wooded and covered with verdure. The mountains which rise from it are volcanic, and the country is described as being surpassingly beautiful.

(*f*) SOUTH AMERICA.—The plateaux of this continent are for the most part of limited extent, but of great height. The *Desaguadero* is the principal one, lying high up among the tops of the Andes, and being some 500 miles long, and from 30 to 60 miles wide. Upon it Potosi, the highest city in the world, stands, and Lake Titiçaca, probably the most elevated sheet of water. Its elevation is about 13,000 feet. The plateau of *Quito*, 200 miles by 30, with the city of Quito, 9543 feet high, is also remarkable. It is on these plateaux of Bolivia and Peru that the greatest difference in the temperature of day and night is found; the days being excessively hot, and the nights intensely cold.

(*g*) AUSTRALIA.—Too little is known of the interior of this great island to enable us to trace its physical features with any degree of accuracy. The country in the north seems to consist of a plateau; and the neighbourhood of the coast generally assumes this character, the land sloping inwards on every side, a feature presented by no other large extent of land.

Elevation.—The height of some of the chief table-lands, is given in the following table, compiled by Humboldt for the most part.

Name.	Height in feet.	Where situated.
Plateau of Auvergne	1,087	France
Bavaria	1,663	Germany
Castille	2,239	Spain
Myson	2,942	India
Caracas	3,070	Venezuela
Victoria Nyanza	3,308	Central Africa
Popayan	5,756	New Granada
Lake Trana	6,076	Abyssinia
Orange River	6,395	South Africa
Axum	7,034	Abyssinia
Mexico	7,483	Central America
Quito	9,528	Andes
De los Pastos	10,231	,,
Eastern Tibet	12,000	Tibet
Lake Titicaca	12,853	Bolivia
Desaguardero	13,000	Andes
Ravanabrada	15,000	Eastern Asia

2. **Low-plains.** Very different in point of importance are the low-plains from those we have just been considering. In the plateaux but few are of such a character as to be useful to man, or even to support a civilized state of society; while it is in the low-plains, which form the greater part of the inhabited

land, that the richest pastures and the wealthiest cities are found. It must not be considered that they possess any marked difference from table-lands; for there are plains, such as the steppes of South America, intermediate in character, and which may, with almost equal propriety, be classed with either. Generally speaking, plains rise gently from the sea, and rise but to moderate elevations, while plateaux rise abruptly and lie at considerable heights above the sea-level. Low-plains are either quite flat, gently undulating, or dotted over with hills and cut up by ravines.

The northern part of the Old World is one immense plain, stretching from Belgium, Holland, etc., to the Oural Mountains, and thence across Siberia to the Pacific Ocean, with but one important interruption in the northerly offset of the Aldan Mountains. This is known as the *Great North Plain.* It receives various names in different parts of its area, under which its several features will be described.

(*a*) EUROPE.—In Europe the great plain is divided into two parts, each possessing distinguishing features; (1) the portion including Belgium, Holland, and North Germany, as far as the River Vistula, and known, at least in the German portion, as the *Landes;* and (2) the *Sarmatian Plain,* extending from the River Vistula to the Oural Mountains.

1. *Heaths and Landes.*—The country included in this division consists for the most part of low-lying sandy tracts, in places extremely sterile, as between the rivers Elbe and Weser, interspersed with heaths, marshes, and occasional pine woods. Its western portion, Holland, etc., lies at or below the sea level, and is brought to a high state of culture, being protected from the sea by banks or dykes, which owe their firmness to the peculiar sand-weed (*Arenaria*), which binds the loose particles together with their tough fibrous roots.

2. *Sarmatian*[1] *Plain.*—This plain extends from the Baltic to the Black and Caspian Seas, and to the Oural Mountains, the Valdai Mountains alone breaking its continuity. It may conveniently be divided into three portions, each having its own peculiarities: (*a*) The Northern, (*b*) the Middle, (*c*) the Southern Divisions.

(*a*) The *Northern Division* extends from the Baltic northwards to the Arctic Ocean, and includes all the country to the north of the Valdai, and as far south as the middle of the Ourals. Much of it consists of marsh-land, and immense tracts are covered by peat, called *Tundra*, which gives its name alike to this portion of the Sarmatian Plain and to its Siberian continuation, where the same peculiarity of soil exists. Swampy, treeless, desolate, it is unfavourable for cultivation, and almost equally so for human habitation.

(*b*) The *Middle Division* is very different from that which has just been described Its climate is mild, its pasture luxuriant, its surface undulating, well watered, and wooded. This division is the most highly favoured portion of Russia. Accordingly it is highly-cultivated; and the squalid inhabitants of the north can dream of no more luxurious paradise than a home in this part of Russia.

(*c*) The *Southern Division*, or the *Steppes*,[2] extends from the River Dnieper along the Sea of Azof, and includes all the country north and east of the Caspian. The general character is a barren, sandy soil, impregnated in many places with salt. These steppes are so remarkable as to merit a somewhat lengthened description; and the following vivid account, by Professor Ansted, can only have been penned by one who has himself suffered the tedium it describes.

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[1] "Sarmatia was the name given by the Romans to the country in Europe and Asia between the Vistula and the Caspian. It is partly Asiatic."—(*Ansted.*)

[2] *Russian, Stepj*, a name applied to these plains.

"In these steppes the seasons are very strongly marked. In the spring and early summer the land is carpeted with flowers. In the summer it becomes parched, after yielding as food or hay a fair supply of mixed grasses, which may be stored for winter use; but in the latter part of summer and autumn it is perfectly bare and burned up. In winter, which begins in October, the whole area becomes covered with snow; and this remains until spring. There are no trees on those great plains, and no inclosures of any kind; but at intervals the surface is broken by hollows scooped out of the plain, to a depth varying generally from 50 to 100 feet; and in most of these are villages and some cultivation, especially on the borders of the plain and in the vicinity of the coast or of the great rivers. There are, however, no roads; and indeed there is no material for making them. One may travel for hundreds of miles over the level surface of the ground—over the turf in spring, through the thick dust in summer, and over the snow in winter—without seeing a single object rising above the general surface of the plain. The post-houses, at equal and distant intervals, are the only signs of humanity and civilization; and the cry of the bustard is one of the few sounds that break the terrible monotony and stillness. The dead level of this pasture, even if luxuriant, soon fatigues the eye; and when the horses and cattle are away, there is absolutely nothing for the eye to rest upon. The travelling across the steppes, conducted with great rapidity in a kind of light cart, is thus not so difficult as it is tiresome. But it is only safe in summer; and when the snows cover the ground, not only does it become dangerous from the wolves who take refuge in the hollows, but almost impossible, owing to the absence of landmarks."

Portions of the steppes, however, go far to redeem this uninviting character, parts of the interior possessing some of the richest and finest corn land in the world. Forests also occur, and fur-bearing animals abound.

(*b*) ASIA.—The steppes, however, are not entirely European, but stretch into Asia, forming nearly the whole of Turkestan, and running into the district of the Obi.

Siberia.—The dreary character of the Tundra has already been described; but we must here notice a singular branch of industry that has arisen of late years—the collecting of fossil ivory. Buried in the swamps are found the remains of elephants, not singly, but by scores; and the ivory obtained from the tusks has become an important branch of commerce. Whether the elephants lived in these desolate regions or whether their remains have been carried northward by the rivers, is doubtful. Certain it is, that they were capable of sustaining a degree of cold much greater than their allies of the present day; for a carcase was discovered frozen into the ice, of which the flesh was so fresh that the dogs commenced eating it before its character was made known. The skin was found to be covered with long, woolly hair, which doubtless served as a protection against the severity of the climate.

China.—The great plain of China is fertile in the extreme, and supports a more crowded population than any other place upon the face of the globe. Rice is the principal crop; and on the low hills tea, the trade in which now supports a fleet of the finest sailing vessels afloat.

Hindostan.—The plains of Hindostan lie between the Himalaya mountains and the Deccan; they are extensive, and from their situation embrace a great variety of climate.

(*c*) NORTH AMERICA. *Prairies.*—The central portion of this continent, from the Rocky Mountains to the Alleghanies, is an immense plain; and its different portions are known as *prairies*[1] or *savannahs*.[2] The prairies are divided into three classes. (1) Heathy, or Bushy Prairies. (2) Dry, or Rolling Prairies. (3) Moist, or Wet Prairies. Of these the Dry division are by far the most extensive; and it is upon them that the stirring events in hunting life occur. Over their vast, unbroken solitudes, the bison and the antelope roam in giant herds, together with countless wild-horses or *mustangs;* the grizzly bear and the wolf here find a home; and the native Indians, but little less free and wild than the beasts they hunt, live out a life so unrestrained and natural as to charm alike the vigorous spirit of youth and the jaded mind of maturer years.

This vast plain is estimated to contain about 3¼ millions of square miles. Year by year cultivation encroaches upon its borders, the wild animals die out or fall back before the white-man's hand, and the red lord of the soil surely and with rapid steps is civilized to death.

The *Atlantic Plain* is a long and narrow stretch of land lying between the Alleghanies and the Atlantic Ocean, and extending from the Gulf of Mexico to Massachusetts. It is fertile, and mostly under cultivation, and upon it stand the largest cities of the United States.

(*d*) SOUTH AMERICA.—From Venezuela to Patagonia, through the entire continent of South America, runs one immense plain, 1900 miles long, and containing 1,620,000 square miles of area. This great plain is known as (1) the *Llanos* in the north, (2) the *Silvas* in the middle, (3) the *Pampas* in the south.

(1) *Llanos.*—These plains extend from Venezuela to

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[1] Fr., *prairie*, an extensive meadow.

[2] Sp., *savana*, a bed sheet, a meadow.

the Orinoco, covering nearly 350,000 square miles (*Ansted*). They are longer from north to south than in the opposite direction, and are nearly destitute of trees, a few palms only occurring here and there. The elevation above the sea is very small; and the slope so slight that the currents of the rivers are destroyed, and high winds will reverse the direction of the stream for a season, and lay wide tracts of country under water. The mean height does not exceed 200 feet. Although the surface of the *Llanos* is peculiarly level, yet two kinds of inequalities occur. (1) *Brancos*, which are level banks of grit, or sand and limestone, running sometimes for several miles with perfect evenness, and raised above the general surface by only five or six feet; and (2) *Mesa*, which are dome-shaped elevations of slight altitude and gentle slope.

(2) *Silvas.*—Bordering the river Amazon, the lowlands are covered with an immense forest called the *Matto*, the district being known as the Silvas. The ground is more uneven than the Llanos, and is covered with so luxuriant a growth as to be almost impenetrable save by monkeys and birds. The forest is 1500 miles long, and on the average nearly 600 miles broad. Much of this district is under water for some months in the year, owing to the inundation of the Amazon, and tribes of Indians dwell continually among the trees, building their villages upon platforms, and travelling either among the tree tops or in canoes.

(3) *Pampas.*—The last division of the great South American plain is the Pampas, which extends from the region of the Silvas to the extremity of the continent; being more than 2000 miles long, and seldom less than 500 miles broad. In the north-west, the Pampas is covered with a thick growth of grass, and wide tracts of huge thistles, which singularly enough have been introduced from Europe. Southwards the Pampas forms an admirable pasture-land, succeeded

by a portion which is rapidly becoming cultivat In Buenos Ayres, the southern part is occupied swamps and lagoons; and south of the Salado Ri the country rises in a series of steps running no and south, which, though verdant in spring-time (autumn) are for the greater part of the year ste plains, strewn with huge boulders of rock, and w large stretches of black lava. Eastern Patagonia 800 miles consists of a desert of shingle. A m desolate region does not exist, and the fierce hurrica that sweep over the country, the chilling blasts hot winds, render it a region to be shunned by shipwrecked sailors sometimes preferring to br the perils of the ocean, rather than risk the c region of this country, and the fierce passions of giant hordes.

C. ISLANDS.

Definition.—Islands are small portions of the la surface unconnected with the larger land-masses continents. They vary in size from mere points which case they form dangerous rocks, to imme areas like Australia. This latter island indeed i large as to be often called a continent.

Classification. Islands are divided into th classes, namely:—

1. Continental islands. 2. Volcanic islands.
3. Coral islands.

1. *Continental islands* are merely seaward extensi of the continents upon whose coast they lie. Thus British Islands are identical in structure with Continent of Europe, and an elevation of 300 would again connect them, by laying bare the wh of the German Ocean.

2. *Volcanic islands* are not necessarily similar structure to the continent near which they

situated, indeed they are often totally unconnected with any continent, as in the case of the Sandwich Isles. The distribution of this class of islands has been noticed under the head of volcanoes.

3. *Coral island* sare described in the article on the Elevation and Depression of Land-Masses. The chief areas in which they occur are Polynesia, the West Indies, the Red Sea, and the Indian Ocean, they being confined entirely to warm latitudes. In the Atlantic, reefs occur as far north as the Bermudas. By far the largest reef in existence is the great Barrier-reef off the north-east of Australia, which is 1200 miles in length.

CHAPTER III.

THE OCEAN.

Distribution of Land and Water.—If we examine a common terrestrial globe, we shall see that by far the larger portion of the earth's surface is covered by water. This water is known as the *Ocean*. The land, it will be seen, is for the most part grouped around the North Pole in a broad belt, which would be almost continuous, but for the separation of the European from the American continent by the Atlantic Ocean. From this belt of land, three comparatively narrow prolongations run into the southern hemisphere, two of them being formed by South America and Africa; and the third, broken in its continuity, by Further India, with its attendant islands of Borneo, Sumatra, and Australia.

Continuity.—The Ocean itself is one and undivided, the land forming, as it were, two gigantic islands—

the New and the Old Worlds—which, however, at their northern extremities, are almost fused into one. It is this continuity which, allowing of a free interchange of the waters of every part of the globe, gives to the ocean its great power as a modifier of climate, and affords a means of communication between distant nations.

Features. The principal features of the Ocean are—(1) *Size*,(2) *Composition*, (3) *Density*, (4) *Colour*, (5) *Phosphorescence*, (6) *Temperature*, (7) *Movements*, (8) *Ice*.

1. **Size**, including (*a*) *Area*, (*b*) *Depth*, (*c*) *Mass*, (*d*) *Weight*.

(*a*) *Area*. The entire area of the surface of the earth is estimated at about 197 millions of square miles; of this the land occupies not more than 51 millions; leaving 146 millions of square miles, or nearly two-thirds of the whole, entirely covered by water.

(*b*) *Depth*.—There are two sources from whence we can derive information respecting the depth of the ocean. *First*, by direct experiment in *sounding; secondly*, by calculations on the breadth and rate of movement of waves, which bear a certain relation to the depth of the water over which they pass.

Soundings are taken by means of a line, marked in fathoms,[1] having a weight attached. This is called a *lead-line*. It is found that when the bottom is reached a distinct check is felt upon the line, which then ceases to run out. This answers very well for moderate depths; but when tried in deep water (say 1000 fathoms) it fails, for no check upon the line can be felt, *neither does it ever cease to run out*. Instances of immense length having been run out are cited by

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[1] A fathom is six feet.

Maury, the great physical geographer of the ocean, without bottom being found. The deepest are:—

34,000 feet or nearly 7 miles by Walsh.
39,000 „ „ 7½ „ „ Berryman.
46,000 „ „ 9 „ „ Denham.
50,000 „ „ 10 „ „ Parker.

It was at length discovered, from a line and weight of the same size being always used, that the time occupied in descending to a given depth was always the same; the weight sinking slower as the depth increased. By observing this time it is possible to "tell very nearly when the ball ceases to carry the line out, and when it began to go out in obedience to the current and drift alone; for currents would sweep the line out at a *uniform* rate, while the cannon-ball would drag it down at a *decreasing* rate" (*Maury*). By means of a contrivance of Brooke's, the cannon ball becomes detached on reaching the bottom, and the line is drawn up bringing with it specimens of the bottom adhering to a little tallow placed in a small cup or in a common quill.

Most of the soundings thus obtained have only been in moderate depths; but in the North Atlantic, whose bed has been more fully explored than any other portion of the ocean, the soundings agree very well with the depth estimated from observations on the tide-wave.

Depth as determined by Observations on Waves.—Mr. Airy, the Astronomer Royal, has shown that a relation exists between the breadth and rate of progress of a wave and the depth of the water over which it passes. And from a consideration of his tables, we have deduced the following laws, which show in a simple manner the data from which depths may be calculated. The *breadth of a wave is measured from the crest of one wave to the crest of another*, and the rate of progress of a wave is estimated at so many *feet in the second.*

Law I.—Waves of any *breadth* may be formed on water of any *depth.*

Law II.—A wave of a given breadth cannot attain more than a certain velocity.

This maximum[1] velocity is never really attained, and can only be approximately attained when the depth is at least equal to the breadth.

Law III.—When the depth is less than the breadth, the velocity—which (by Law II.) never attains its maximum, increases nearly up to a certain speed.

This speed is attained when the breadth equals a 1000 times the depth.

So that waves whose breadth is more than a thousand times the depth, move sensibly only at the same rate as those whose breadth is simply equal to the depth.[2]

We see from the above that the speed of a wave increases according to a certain law, so that if the breadth be given its maximum rate can be calculated. For instance, a wave 100 feet broad formed on water 100 feet deep, travels at about the rate of 20¼ feet per second; and if we imagine it to be rolling over deeper and deeper water, it would not acquire any higher speed for (Law II.) it would have already reached its maximum rate of progress.

Suppose now the wave to become broader, say to 1000 feet,—still in 100 feet of water,—it would increase in velocity up to about 53 feet per second; still growing broader it would go on increasing in speed until the wave became 100,000 feet broad, by which time its speed would be about 57 feet per second; after this it could progress no faster, however *broad* the wave might become (Law III.). But if the water grew deeper, the rate would again increase (Law II.), and if we could have so great a depth, would attain its maximum of 715 feet per second in 100,000 feet of water, and so on.

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[1] L., the greatest.

[2] The Astronomer Royal has kindly examined this exposition of the theory of waves.

In applying the above laws, which constitute what is known as the "Theory of Waves" to actual cases, it is, of course, necessary to select a wave whose breadth is beyond doubt greater than the depth of the water can be; otherwise no satisfactory result can be obtained. For if the wave be moving at its greatest speed all that can be said of the depth is (Law II.) that it cannot be *less* than the breadth of the wave. Hence it is that the great waves caused by earthquakes and the tide-waves, are chiefly selected; the former being many hundreds and the latter many thousand miles broad, their breadth being measured from the crest of one tide to the crest of the next, 12 hours later.

The depth of the Atlantic has been calculated by Herschel from the tide-wave, which in that ocean is 6000 miles broad, and travels over a space equal to its own breadth in 12 hours, that is, it moves at the rate of 731 feet per second. This gives an average depth of 22,157 feet, or about four and a quarter miles, a result which perfectly accords with what we know of its basin from soundings.

The mean depth of the Pacific Ocean was estimated by Bache from the gigantic waves formed by the earthquake in Japan, of Dec. 23, 1854, which rolled right across the ocean, and were self-registered on the tide-gauges on the coast of California. He found the breadth of these waves at 217 miles, and their rate $6\frac{1}{10}$ miles per minute, or 537 feet per second. By the theory of waves he concluded the mean or average depth of the Pacific Ocean to be 14,190 feet, or about two and a half miles.

From our very limited knowledge of a great portion of the Ocean, we can of course form no certain estimate of the mean depth, but we may assume it to be about four miles. "A result," says Herschel, "as likely to be beyond the truth as within it."

(*c*) *Mass.*—Taking the area of the ocean at 146 million square miles and the average depth as 4 miles, we find the number of cubic miles of water to be 584 millions.

(*d*) *Weight.*—From the above data it is easy to estimate the weight of the ocean. Sea water at the surface has a density of 1·026 (pure water being 1.) The weight of a column of sea water two miles high is equal to 318·3 times the weight of the atmosphere. This weight is sufficient to compress the water at that depth ·015105, making the density 1·0414926, or nearly 1·0415, which is the mean density of sea water, supposing the ocean to have an average depth of four miles.

Now a cubic foot of sea water at this density weighs 65·09 lbs, and a cubic mile 4,271,369,142·8 tons; this number multiplied by 584 millions gives as the weight of the ocean 2,494,500 billion tons nearly, or about $\frac{1}{2846}$th of the weight of the globe.

Prof. A. S. Herschel has favoured us with the following illustration. "The weight of the sea is to that of the atmosphere as 479·5 (very nearly 480) is to 1, or, according to the *apothecaries' division* of the *avoirdupois ounce*, almost exactly what a fluid avoirdupois ounce of water is to a minim or 'drop' of the same liquid. On this scale the globe of the earth itself would be represented by a sphere of mineral of the same density as itself (5·5), 11 inches (11·2) in diameter, on the surface of which the fluid ounce of sea would have to be spread over an area of almost exactly *two square feet*, and the drop of atmosphere over its whole surface."

2. Composition.—The saltness and bitterness of sea-water is due to the presence of soluble matter, such as sodic chloride, or common salt, which exists in greater quantities than any other saline material. Magnesia and lime come next in point of abundance, occurring as carbonates, sulphates, and chlorides; and then follow numerous bodies, such as magnesic bromide, various iodides, silica,[1] or sand, and, indeed, traces of almost every soluble substance, for the rivers are constantly discharging immense quantities of dissolved material into the sea, which must remain there, since they cannot be evaporated. Copper is said to occur; for on trailing a bar of polished iron after a ship, it has been found coated with a film of that metal at the end of a voyage. This may be the result of the galvanic action of sea-water upon the ship's copper bottom; and the experiment should be tried from iron ships to afford a satisfactory result. Silver is also known to be dissolved in the sea, and the copper of old ships has been found to contain sufficient to pay for its extraction.

The amount of salts dissolved in the ocean is about 3½ per cent, and taking their specific gravity to be 2, or about that of common salt, we find that a cubic foot of these salts weighs 125 lbs, and a cubic mile 8,214,171,428·571 tons. Now as the salts amount to 3½ per cent of the whole ocean, we find the number of cubic miles by taking 3½ per cent of the whole, that is 20,440,000 cubic miles. This number multiplied by the weight of one cubic mile of salts, gives as the weight of the salts dissolved in the ocean about 167,898 billion tons.

The degree of saltness of the ocean is almost everywhere the same. The mean amount of saline material is about 4 per cent. This uniform saltness of the ocean is the result of the constant interchange of waters in every part of the ocean, and would not therefore, be maintained if the ocean were not continuous. Even as it is, the sea is found to be *slightly* salter in the regions swept by the trade-winds, and somewhat fresher in the Polar regions, owing to the melting ice and snow.

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[1] Lime and silica are important, as supplying the hard parts of fishes, shells, and other marine organisms. From the former coral-reefs, from the latter great deposits of tiny shells upon the sea-bed, are formed.

Still, a remarkable uniformity of saltness does exist. The Red Sea, for example, through whose thirsty shores no river finds its way, and upon whose surface rain never falls—lying, moreover, scorching in the torrid zone, and, therefore, sustaining an excessive evaporation with no compensating influx of fresh water—would be much salter than the open sea, unless the dense water somehow found its way out again. But its waters are not sensibly salter than those of the Indian Ocean.

Fresh water entering the sea by rivers, or as rain, does not readily mix with salt water, and being lighter, floats on its surface. Fresh water has been taken up from the ocean, out of sight of land, off the mouth of the River Amazon; and in the tropics, where rain is almost constant, sailors report pools of fresh water in the same way.

3. **Density.**—A cubic foot of fresh water weighs 1000 ounces, while the same quantity of sea-water weighs 1026 ounces. In other words, sea-water is heavier than fresh water. The density is not always the same, but varies with the amount of salts present, being densest where the amount is greatest. Speaking generally, the Atlantic is salter and denser than the Pacific, and the southern parts of both oceans denser than the northern parts. The following table shows the density of the water from different parts of the ocean, fresh water being 1:—

North Atlantic	1·02664	**Indian Ocean**	1·0263
South ,,	1·02676	**Mediterranean**	1·0289
North Pacific	1·02548	**Red Sea**	1.0286
South ,,	1·02658	**Baltic**	1·0086

4. Colour.—The colour of the open sea is a deep blue, passing into bright green as the water becomes shallower. A white object thrown overboard in deep water is seen to become green as it sinks. The origin of this colour is not satisfactorily made out. It has been supposed to be due to the presence of salt, an idea which derived its support from the observed fact of the water in salt-pans becoming blue as the brine grows more concentrated. But this does not explain, for instance, why the Mediterranean, which is not salter than the ocean, is so much more brilliant in hue, neither does it show why many lakes and some rivers, which are, of course, not salt at all, possess water as pure in tint as the Mediterranean itself. The river Rhone on its issue from Lake Leman, is an illustration of this.

Others have supposed the colour, like the blue liquids in druggists' shop windows, to be due to the presence of some salt of copper.

It is most probable that the blue and green tints are colours belonging to the water itself; and sea-water only assumes other hues where it happens to be charged with solid matter in suspension—*i.e.*, not *dissolved* but held up by the motion.

The Red Sea is supposed to derive its name from a microscopic plant of that colour which is sometimes thrown up in vast quantities on its shores. In the Gulf of Akaba, quantities of the red organ-pipe coral (*Tubipora musica*) are deposited on the beach; and this may have given rise to the name in early times. The sea itself is as blue as the Atlantic; and navigators assure us that a red tinge is scarcely, if ever, observed. The Gulf of California is sometimes called the Vermilion Sea, from its assuming that colour. At the mouth of the La Plata the sea is also occasionally red. In the Pacific Ocean patches of a red colour many miles across are observed, which, on investigation, are found to be due to the presence of animalcula.[1] Similar patches of *brown* and *white* colours are not unfrequent in that area.

The eastern portion of the Mediterranean is often tinged with *purple*.

The Yellow Sea is so named from its colour, due largely to the sediment discharged into it by the great rivers.

The waters of the Gulf of Guinea often appear of a *white* colour. Snow-white patches have been alluded to as occurring in the Pacific area; and around the Maldive Islands the sea sometimes acquires a *black* cast.

These various hues are probably due in every case to the presence of solid matter, whether as living organisms or as sediment; and are not, like the blue and green colours, proper to the water itself.

5. **Phosphorescence.**—One of the most beautiful aspects which the face of the ocean presents to us is this phosphorescence. Under the most varied conditions, in the still darkness as well as in the stormy night, in warm tropic seas as well as chill polar waters, this phosphorescence may be observed. We have seen it fitfully gleaming over the sleeping waters, and again gilding with burning light every wave and ripple within sight. Sometimes so pale as to seem spectral in its whiteness, sometimes glowing in a ship's wake so powerfully that books may be read by its light. At times it studs the sea like myriad water-stars, and on pouring the water through the hands the fiery points will adhere to the fingers, glowing all the while. Great globes of living fire well up from beneath the ship's keel, or irregular patches constantly changing in outline float around. Every now and then a flash of fire is propagated across the surface, and all remains dark until illumined by another similar display. Such are some of the many phases

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[1] L., *animalculum*, a little animal.

this beauteous phosphorescence presents to charm away the monotony of the sea and relieve its tedium.

Most of these effects are produced by minute light-emitting animals, some of them doubtless by shoals of small fish, to which especially we would refer the irregular changing patches above mentioned. These may often be dissipated, as it were, in a shower of sparks by throwing something into the midst of the shoal, when the frightened individuals at once scatter. Many of these minute phosphorescent beings are of strange, weird shapes, and a rich field of investigation still lies open for the naturalist in that direction.

The light is usually of a pale greenish character, similar to that of the glow-worm, but sometimes it loses this greenish cast, and as the water drips from the oars, they seem as if bathed in moonlight.

6. **Temperature.**—The temperature of the surface water of the sea is nearly that of the air above it, varying only where currents sweep along, raising or depressing the temperature according as they are hot or cold. Water, being a bad conductor, takes longer to become warmed, and retains the heat longer than air, so that the mid-day temperature is somewhat below, and the mid-night temperature slightly above, that of the air. Hence it is that the sea is so much less variable in temperature than the land.

All over the world, at great depths, cold water of the same temperature has been recorded, namely 35° F., or 3° above the freezing point of fresh, and 7° above that of salt water. In hot and temperate regions there is warmer, and in cold regions colder, water above this uniform layer. The dividing line between these regions being, of course, the *isotherm* of 35° F., or the line where the mean annual temperature equals that amount. At the equator, this uniform layer of cold water is reached at the depth of 7,200 feet, and in the highest accessible latitudes at 4,500 feet.

7. **Movements.**—We will now consider the movements which take place in the waters of the Ocean, and which are of two kinds—*Currents* and *Waves.*

A. CURRENTS.

Origin.—The principal causes of currents are—

(1) *Winds.*
(2) *Evaporation.*

1. **Winds.**—The winds are the chief originators of currents, imparting to the water motions in the same direction as that in which they blow. It will be necessary, in order to understand the system of ocean currents, briefly to describe the main features of the winds in this place, leaving a fuller examination of the subject for another chapter. It must be remembered that the *direction of a wind* is that *from* which it blows, the *direction of a current* that *to* which it runs. So that a *north-east* wind and a *south-west* current travel in the same direction.

The earth is divided into four distinct wind-regions, two of them characterised by winds which steadily blow in the same direction, and called the Trade-wind Regions, and two in which the direction of the wind is variable, and called the Regions of Variable Winds, and also, from the general direction of the winds being opposite to that of the Trade-winds, these regions are known as the Regions of the *Anti-trades.*[1]

The *Trade-winds* blow from near the tropics to the equator; in the north they have a north-east direction, and are called the *North-east Trades,* and in the southern region they blow from the south-east and are called the *South-east Trades.* In the Indian Ocean the North-east Trades have their direction modified according to the seasons, and are called the *Monsoons.*

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[1] **Antitrade, *against* the trade wind. The prefix *anti* is Latin.**

The *Antitrades* extend from the trade-wind regions to near the poles: they are very variable, but their general direction is towards the poles. In the northern region south-westerly currents of air prevail, called the South-west Antitrades; and in the southern regions the prevalent winds are from the north-west, forming the North-west Antitrades. The following diagram may assist in remembering the *direction* of the winds. The arrows being supposed to fly *with*

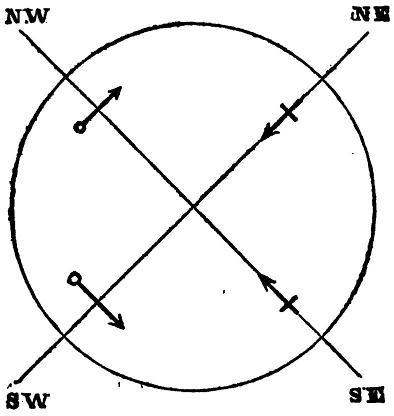

FIG. 4. DIAGRAM SHOWING THE DIRECTION OF THE WIND.

the wind; +→ representing the Trades, o→ the Antitrades.

2. **Evaporation.**—Evaporation is the action of the sun's rays in raising water from the surface as invisible vapour, or, in common language, in "drying up" a portion of the sea water. It affects only the water, and leaves the salts untouched; hence, the water, becoming heavier, sinks, and becoming lessened

in quantity, currents of lighter, fresher waters set in from the poles, to supply the loss, and at the same time currents of heavier, salter waters run towards the poles. But this action, as compared with the power of the winds in producing currents, is *very slight, and is perhaps wholly concealed by their overpowering influence.*

System of Currents.—The trade-winds being the prime cause of currents, if we suppose the earth to be covered entirely with a uniform depth of water, it will be easy to see what is their true effect. Blowing towards the equator from both sides, they will give to the water motions in the same direction, and these south-west and north-west currents meeting there, would unite and flow westwards, thus giving rise to a great equatorial current running right round the globe.

1. **Equatorial Current.**—This current actually does exist, and is only prevented from performing its majestic tour round the earth by the land masses. They divide the ocean into three basins, so that the Equatorial Current has to be formed separately in the eastern portion of each ocean, to be broken up again on the western coast.

(*a*) *Pacific Ocean.*—The equatorial current of the Pacific Ocean is formed within the tropics, and sweeps steadily across from the American to the Asiatic coast, meeting which, it splits in two, or *bifurcates*,[1] and the larger portion, turning southwards, escapes between the islands of the East Indian Archipelago into the Indian Ocean. The rest, flowing northward, keeps outside the islands of Asia, forming what is known as the *Japan Current;* still continuing its course northwards, it sends a small branch through Behring's Straits into the Arctic Ocean, while the main portion continues to sweep round the coast, and turning southwards creeps along the Californian coast, and finally joins the equatorial current again, after having performed the grand circle of the entire North Pacific basin.

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[1] L., *bis*, twice, and *furca*, a fork: to divide into two branches.

(*b*) *Indian Ocean.*—In this ocean, notwithstanding the monsoons destroy the simplicity of the trade-wind influence, the equatorial current is still distinctly traceable south of the equator, and receiving the branch of the Pacific current, it pursues its westerly way, until, at some distance from Madagascar, it bifurcates, part going north of Madagascar, and then, curving southwards, runs between that island and the coast of Africa as the *Mozambique Current;* the other portion runs directly towards the Cape of Good Hope, joining the Mozambique current on its way. Only a small part of these united currents passes round the Cape as a warm current, the greater portion being suddenly deflected or turned back by a cold current from the south, which will be noticed by-and-by, and, running almost due east, re-enters the Indian Ocean.

(*c*) *Atlantic.*—In the Atlantic Ocean the splitting up of the equatorial current takes place off Cape St. Roque in South America, the smaller portion turns south, forming the *Brazil current;* and its further course is not satisfactorily made out, but most likely it goes to form the *South Atlantic Connecting Current,* running easterly, and may then be returned to the equatorial circulation. The main branch, increased and strengthened by the south-west drift of the North Atlantic, having its origin in the north-east trades, is driven into the Caribbean Sea, thence through the Straits of Yucatan into the Gulf of Mexico, round which it eddies, and finally issues through the Straits of Florida as the renowned *Gulf Stream.*

2. **Gulf Stream.**—This majestic current, whose origin has just been described, is 30 miles broad, 2200 feet deep, and travels at the rate of about

four miles an hour, when it issues from the Straits of Florida. Its temperature is very high (86° F.), and it is this circumstance to which it owes its importance as the great warmth-giving agent of the climate of Western Europe. The northward direction of this current is so modified by the daily rotation of the earth, as to take a north-easterly course.

To understand this action of the rotation of the earth upon the direction of currents—and it is a subject that must be well understood, as it will have to be again alluded to in the chapter on winds—the following illustration may assist.

[1] Take a common terrestrial globe, bring any place in the northern hemisphere under the brazen meridian; put a finger of the left hand on the place, then moving the finger down along the meridian to the south, to represent a drop of water, turn the globe on its axis from west to east, to represent the daily motion of the earth, and when the finger reaches the equator, stop. It will now be seen that the place on the globe under the finger is to the southward and westward of the place from which the finger started; in other words, the track of the finger over the surface of the globe, like the track of the drop of water upon the earth, has been from the northward and eastward. But to reverse this process would not give a correct idea of the direction of a drop of water going from south to north, like the Gulf Stream. For in coming *from* north to south, as we have supposed, the movement is towards those portions of the earth which revolve faster than the place from which the drop started; whereas in travelling *towards* the north the drop sets out with a motion towards the east greater than that of any portion of the surface over which it will travel. (p. 18.) To make this plainer, suppose it were possible to see Ireland from the

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[1] These two illustrations are adapted from Maury.

Straits of Florida, and to get a cannon to reach so far, a person in the Straits intending to shoot at Ireland as a target, would, if the earth were at rest, aim direct. But the earth revolves on its axis, and the Straits being nearer the equator than Ireland is, the gun would be moving faster than the target, and therefore the marksman would miss. He would find that he had shot to the right of the object.

Now the Gulf Stream, like the cannon-ball, partakes of this rapid motion, and is in like manner carried to the right, that is, the east. With this easterly tendency it runs towards the bank of Newfoundland, gradually spreading itself out as the surrounding waters become colder. In about latitude 43° N., this spreading, or thinning out, has entirely destroyed the Gulf Stream as a distinct current, and a large portion of its water curves east, and running south rejoins the equatorial circulation, thus forming a circle or eddy similar to that in the North Pacific Ocean. In the centre of this great eddy, about the tropic of Cancer, is an immense accumulation of floating sea-weed, known as the *Sargasso Sea*, which extends from about lat. 18° to 28° N., and from long. 20° to 65° W. The weed is chiefly *Fucus natans*, and maintains a rich world of *crustacea* and *mollusca* [1] on its bosom.

The remaining waters of the Gulf Stream, aided in their course by the south-west antitrades, enter the North Sea as a *drift* current (that is, a general set of the water in a certain direction, but *not* confined within comparatively narrow limits as in an ordinary current) of warm water, raising the temperature of Western Europe, which would otherwise possess a climate as rigorous as that of Labrador; thence passing into the Arctic Ocean, it becomes chilled, and re-issues, partially at least, into the Atlantic as the Arctic current between Spitzbergen and Greenland.

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[1] *Crustacea* are such animals as crabs and shrimps. *Mollusca*, such as oysters, cockles, and whelks.

The waters of the Gulf Stream do not mix with those of the surrounding ocean, and being clearer and bluer in tint, the line of demarcation between them is so remarkably distinct, that it is easy to see exactly when a ship enters them.

3. **Other Currents.**—Having now traced the course of the great equatorial current and its branches, we will consider the remaining currents, commencing as before with the—

(*a*) *Pacific Ocean.*—In the Northern Pacific Ocean, encircled by the equatorial current and its eddying stream, is a curious and complicated system of currents, but ill understood. They run eastward, parallel with, but in an opposite direction to, the great equatorial current, and hence are called "counter" currents. Herschel has suggested that they may arise from shallows in that region.

From what has been said of the circulation of the waters in the Pacific, it will be remembered that while in the north they merely sweep round its basin, the southern waters find their way into the Indian Ocean. So that the South Pacific would be drained of its waters, unless replenished by an indrift from the south. This is accomplished by two currents, which are known as the *Antarctic Drift Current*, of cold, iceberg-laden water, and the *South Pacific Current.*

These southern waters would naturally flow in a *south-east* direction, driven by the north-west anti-trades. Being compelled to take a northerly course, to supply the deficiency in the South Pacific, their southerly tendency is overpowered, and the easterly impulse left unchecked carries the waters in that direction.

The *South Pacific Current* setting in towards the coast of Peru, breaks up, sends one portion southwards round Cape Horn into the Atlantic, forming the *Cape Horn Current;* and the rest forms two currents running north, one, the *Peruvian Current,*[1] creeps along the coast and joins the equatorial current in lat. 4° S.; the other, the *Mentor Current,* keeps further out to sea.

(*b*) *Indian Ocean.*—This ocean resembles the Pacific in being closed to the north and open to the south, and its currents are also similar. In the north, however, the circulation is modified by the monsoons, and the waters flow in different directions according to the direction of those winds.

From the south, this ocean is replenished by a drift current, in the same manner as in the Pacific. It is this current that pushes back the Mozambique Current, as described above (p. 73). It runs in a north-east direction towards Australia, and bifurcating off Cape Lewin, sends one portion along the west coast of Australia to join the Equatorial Current, and another along the South Australian coast into the Pacific.

(*c*) *Atlantic Ocean.*—The currents of this ocean have already been described.

4. **Classification of Currents.**—The currents of the ocean may be classed as follows:—

(*a*) *Stream Currents,* flowing in one direction, like "rivers in the ocean." Such are the *Gulf Stream,* the *Equatorial Current,* etc.

(*b*) *Counter Currents,* such as run alongside, but in opposite directions to other currents, as the *Pacific Counter Currents.*

(*c*) *Variable Currents* change their direction in obedience to the influence of winds or tides. Such are the currents in the North of the Indian Ocean.

(*d*) *Drift Currents* are movements of the water which do not possess the river-like character of other currents, but are merely a general motion or "drift" in a certain direction. Such is the Antarctic Drift Current.

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[1] *This is also called Humboldt's Current.*

B. WAVES.

Waves are of three kinds, and are named according to their origin:—(1) *Wind-waves*, (2) *Earthquake-waves*, and (3) *Tide-waves*. The two former are very much alike, differing only in magnitude; but the last possesses peculiarities which distinguish it at once from all other waves.

Nature of Wave Motion.—Before entering into a particular description of the various kinds of waves, it is of the first importance properly to understand the nature of wave-motion, or very incorrect conclusions may be formed respecting them.

A little consideration will show that the motion of the water is only apparent. Standing upon a beach when the tide is ebbing, it will be noticed that the waves continually *roll in towards the shore*, notwithstanding that the movement of the water is in the opposite direction. Again, waves are often seen on rivers *travelling in an opposite direction to the current.* These two illustrations show that the wave may have a motion in one direction, and the water at the same time be moving in another direction. If the water really moved as it appears to do, a ship would be carried along by the waves, instead of which they pass under her, alternately raising her on their crests and then letting her sink again into their troughs.

A last and familar instance of wave motion is seen in shaking carpets, when the two ends of the carpet, grasped in the hands remain stationary, while "waves" are propagated from one end to the other. In this instance it is at once evident that it is not the carpet that moves, but merely the *form* that travels from one end to the other. This fact, then, must be continually borne in mind, in treating of waves:—The motion of the water is *apparent*, not *real*, what really moves is the *form* of the wave. In other words, a wave, as it progresses, is not composed of the same water. The following diagram (Fig. 5) will show what the movement of the particles of water composing a wave really is.

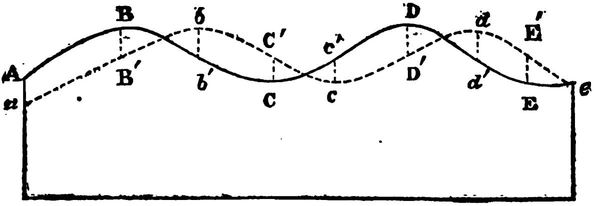

FIG. 5. DIAGRAM SHOWING THE NATURE OF WAVE MOTION

Let A, B, C, D, E represent the surface of the water, and B, D the crests of two waves, and C, E their troughs, the motion being in the direction from A to E. Let *a*, *b*, *c*, *d*, *e* be the position of the waves after the interval of a few seconds. To bring about this change of position, the water at A has *sunk* to *a*, that which was at B to B′, the water which was at *b*′ has *risen* to *b*, that which was at C to C′, that which was at *c*′ has sunk to *c*, and so on. From this it appears that the advance of the wave is produced without any advance of the water, but by its particles rising and sinking alternately in a vertical direction.

1. **Wind-waves.**—Out at sea, when there is no wind, the surface of the deep is as smooth and bright as the face of a mirror; and the weary mariner, thus becalmed, looks anxiously for the first puff of air betokening the coming of the longed-for wind. This is seen afar off by its ruffling the bosom of the waters, and making them appear dark in comparison with the shining surface; and if the wind blow in

puffs, the tiny ripples speed over the surface, dying away as rapidly as they are formed. This is what the sailor calls a *cat's-paw;* and in this manner, from such slight beginnings, are born the mightiest waves. Each "wavelet," as it advances, becomes increased in height by the continued pressure of the wind; and the height it ultimately attains is dependent upon the breadth of the water and the continuance of the wind. A long-continued steady breeze would raise larger waves than a squall, which, though blowing with many times the force of the breeze, is yet rapidly spent.

The relation between the breadth of a wave, its rate of progress, and the depth of water over which it passes, has been dwelt upon at length in another place (p. 61); but we must here notice the fact, *that the depth to which the disturbance of a wave is felt is very slight.* The motion growing feebler so rapidly, that at a depth equal to the breadth of a wave, the movement is only $\frac{1}{584}$ of that at the surface. It has been calculated that a wave a quarter of a mile broad and 40 feet high (that is, as high as the largest wave off the Cape of Good Hope) would be incapable of moving a grain of sand at the depth of a quarter of a mile (1320 feet); which is of course much less than the depth of the ocean.

A wave is not only elevated above the general level of the sea, but is also depressed beneath it; its trough falling as much below that level as its crest rises above it. The height of a wave is measured from its trough to its crest or summit. The largest waves are those formed off the Cape of Good Hope and Cape Horn, which sometimes attain the height of from 30 to 40 feet. In our own seas they rarely exceed 8 or 9 feet in height.

(*a*) *Surf.*—When a wave reaches shallow water, its lower portion is retarded by friction on the bottom, and the upper portion, unchecked in its motion, continues and eventually breaks, topples over, and rushes up on shore while the lower portion at the same time races back. In this way *surf* is formed, which in some places, where large waves formed in the open sea roll on to a shallow coast, attains such a magnitude as to render landing on such a coast at all times an uncomfortable, and sometimes a dangerous operation. On the West Coast of Africa, a tremendous surf is produced in places, which tears the beach up with enormous force; and the great sharks lying in wait for prey destroyed by the breakers, are often themselves overwhelmed in its fury and dashed lifeless on the beach. The Malabar coast of India also, is fringed with heavy surf, the waves often breaking several miles out to sea. In the case of waves thus impeded by shallows, a motion is actually imparted to the water, and the wave, thus changing its nature to some extent, is sometimes called a *wave of translation.*[1]

(*b*) *Chopping Sea.*—When a series of waves flowing in a certain direction meets another series proceeding in a different direction, they cross, but do not become confused; and thus break the surface of the water into squares or lozenges, according to the angle at which they meet. This produces what is called a *chopping sea,* and the effect of the twisting motion given to a vessel under such circumstances "can be better imagined than described."

A chopping sea may be produced in several ways, (1) by a series of waves meeting another series, reflected from the shores of a large bay—as in the Bay of Biscay. (2) When the wind, after blowing steadily in one direction, suddenly changes or *veers,* the waves produced by the wind in its former direction, meeting those resulting from its new direction, cause a chopping sea. (3) Sometimes a heavy sea is experienced in tolerably calm weather, derived from some distant storm; this is what is called a *ground-swell*, and if this ground-swell comes from a direction different from that in which the wind is blowing, a chopping sea is the result.

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[1] L., *trans,* "across," or "over," and *fero, latum,* "to bear." It has here its original signification.

(*c*) *Force of Waves.*—The force of waves, when acting against an obstacle, is very great. A sad illustration of their power is but too often observed, in the speed with which an unfortunate ship, driven upon the rocks, breaks up under their influence. Sunken vessels, long buried beneath the sea, are often torn up and cast upon the shore in heavy storms. Waves have been known to dash right over the Eddystone lighthouse, 150 feet in height, and descend with a crash upon its summit. The same has been observed at Bell Rock Lighthouse, 100 feet high; at Dunnet Head the lantern, 270 feet above the sea, is cracked by pebbles hurled from the beach by the waves. During very violent storms, the Atlantic waves rush nearly 600 feet up the sides of the cliff at Hoy Head, in Orkney. The pressure in violent storms has been estimated at 6000 lbs. on the square foot, a force which shows what enormous strength must be given to breakwaters, to enable them safely to resist their impact.

2. **Tide-waves.**—These waves, as we have said, are very different in their nature from those above described. Their differences can be most readily seen by such a comparison as is exhibited in the following table:—

Wind-waves	*Tide-waves*
Affect the surface water only.	**Affect every portion of the water equally.**
A cork floating on waves of equal breadth and height, revolves in a vertical circle.	**A cork similarly floating on the tide-wave would revolve in a very elongated ellipse, the**

	shortest axis of which would be vertical. This ellipse would be half the circumference of the globe (12,500 miles) if the whole earth were covered with water.
The water composing a wind-wave rises and falls vertically, as has been explained.	The water composing the tide-wave has a *lateral*[1] motion, moving from a quarter of the globe on either side, to form the elevated portion of the tide-wave.
Wind-waves travel in all sorts of directions, according as the wind blows.	Tide-waves always travel in one direction, at any given place.

(*a*) *Origin of Tides.*—The common idea of the origin of the tides is, that the moon attracts, or draws the water to that side of the globe on which it happens to be placed. But, like most such ideas, it neither explains the phenomena of the tides, nor accords with the known facts. For if such were their origin, high tide could only be formed under the moon; and as the moon passes over a place only once a day, that is, in the course of a revolution of the earth on its axis, only *one* tide could occur daily. Whereas the fact is that *two* tides take place in the course of one day; there being a tide formed, not only directly *under* the moon, *but on the opposite side of the earth, directly opposite to the moon's position, at the same time.* This common notion, then, does not accord with the facts; and it is as easy to show that it would not explain them *if it did.* If the moon attracted the earth in the manner supposed, *there is no reason why the waters should be heaped up at all*, for the solid parts of the earth, being equally attracted with the liquid parts, would be equally drawn towards the moon, and the solid and liquid parts would thus maintain their relative positions. It is thus shown that the simple attraction of the moon does not *explain* the origin of the tides.

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[1] L., *lateralis*, from the side.

What really happens is, that the moon attracts *different portions* of the earth *differently at the same time,* attracting one portion more powerfully than another; and the sun does the same. To understand *how* this attraction acts upon the earth, let us see by what laws it is governed. This attraction is known as the *attraction of gravitation,*[1] and it acts in *the inverse proportion of the square of the distance.* This means that the attraction of any body, say the moon, acting at a given distance, say 1,000,000 miles, would be *four* times as much (2 × 2) at *half* the distance, or 500,000 miles; *sixteen* times as much at a *quarter* the distance (4 × 4), or 250,000 miles; *one-fourth* of that amount (2 × 2) at *double* the distance, 2,000,000 miles; *one-ninth* (3 × 3) at *three* times the distance, 3,000,000 miles; *one-sixteenth* of the amount (4 × 4) at *four* times the distance, 4,000,000 miles, and so on.

(*b*) *Lunar Tides.*—Now, to apply this to the case of the moon's attraction on the earth. Let us again suppose the whole earth to be equally covered in every part by the ocean. Let A, B, C, D, E (Fig. 6) represent the solid earth, and Z, N the covering ocean; M being the position of the moon.

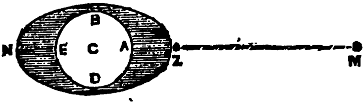

FIG. 6. DIAGRAM OF LUNAR TIDES.

It will be evident that the attraction of the moon upon the earth at A, where it is nearest, is greater than it is at B or D, which are more distant, and still greater than at E, which is the farthest removed. Again, the attraction of the moon upon the water at Z, where it is nearest, will be greater than its attraction upon any other portion of the water, and at N, which is directly opposite the moon, the attraction will be least of all.

---

[1] From the Latin word *gravis*, heavy; for the attraction increases with the mass or weight of the body.

Now, there is this difference in the effect of the attractive force upon the solid and liquid portions of the earth, that while the fluid portion is more or less free to obey the attracting force, and is therefore drawn towards a point directly under the moon, the solid portion coheres together so strongly that it must obey this attraction as a whole, as the relative position of its particles cannot be disturbed.

The results of this inequality of attraction upon different portions of the earth, are as follow:—

i. The *waters* at Z being nearer to the moon than the solid earth at A are attracted with greater force, and being free to move, heap themselves up in a wave underneath the moon, the water flowing towards the place in order to effect this.

ii. At the same time the *solid earth* at E being nearer than the waters at N, is attracted with greater force. By reason of this the earth approaches towards the moon, leaving the water behind it.

In this way the two *contemporaneous* [1] tides are formed, the one directly under the moon and the other exactly opposite to it. And this is effected, not by the mere attraction of the moon, but *by the inequality of its attraction upon different portions of the earth.*

Now as the earth revolves on its axis, every portion of its surface D E B passes in succession under the moon, and under the opposite point N; and as at each of these points there is *high water*, or *high tide*, it follows that at every place there are two tides daily.

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[1] L., *con*, together, and *tempus*, time; meaning, *occurring at the same time.*

(c) *Solar Tides.*—Everything we have said respecting the attractive force of the moon applies equally to the action of the sun; so that there are sun or *solar*[1] tides, as well as moon or *lunar*[2] tides. But the solar tides being smaller than the lunar tides, do not form tide-waves, but act as *draw-backs* when the moon's position is in front of the sun, and as *aids* when the sun's position is in front of the moon; causing the tides to form slower and to be less in the former case, and to form quicker and be larger in the latter case.

The sun is about 400 times as distant from the earth as the moon is; his attraction therefore is 160,000 (400 × 400) times less than that of the moon. But as the sun's mass is nearly 28,400,000 greater than the moon, it must therefore exert a much greater effect upon the earth. This it actually does; and if the tides resulted simply from the *amount* of attraction, the solar tides would greatly exceed the lunar tides. But, as we have seen, the tides are due to the *difference* of the attractive force upon different portions of the earth; and knowing, as we do, how to calculate that attraction, it is easy to show how it comes to pass that, though the sun exercises so much greater an influence upon the earth than the moon does, it yet produces smaller tides.

The attraction of the sun or moon upon the whole mass of the earth is the same, of course, as if it were collected at the centre C, fig. 6, and the attraction upon the waters upon the near side of the earth the same as if it were collected at z, fig. 6. It is clear that the attraction upon z is greater than upon C, for it is nearer; and to find the amount of attraction available to form a tide, it is only necessary to find the amount of attraction upon C and z, and their *difference* is the power available to produce a tide. In the case of the moon it is found to be about 1-30th of its attraction upon the whole earth, and in the case of the sun only 1-12,000th part. The moon therefore would produce a tide 400 times (12,000 ÷ 30) greater than the sun, *if it were the same size.* But it is much less than the sun (p. 86), and therefore exerts a less influence. Now as the sun is 400 times farther from the earth than the moon is, its influence is diminished in the proportion of 160,000 to 1 (400 × 400). This causes its actual attractive power to form a tide to be less than that of the moon in the proportion of 1 to 2½; that is, the moon actually possesses 2½ times the power to form a tide that the sun has. Thus is explained how it is that the lunar is greater than the solar tide.

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[1] *L., sol,* the sun. [2] L., *luna*, the moon.

(*d*) *Spring and Neap Tides.*—When the sun and moon are on the same side of the earth, as at new moon, the lunar and solar tides are heaped one on the other, and a very large tide is the result. The same thing happens when they are on opposite sides of the earth, as at full moon. But when in other positions, the two tides act against one another; and when they are ninety degrees apart, they are *diametrically*[1] opposed to each other, and a very small tide is the result. In the former case, the tide is the sum of the two tides, and is called a *spring-tide;* in the latter case it is their difference, and the tide is called a *neap-tide.*

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[1] *Diametrically*, Gr., *dia*, through, and *metron*, a measure, meaning *directly*, or in the direction of a diameter.

This will be easier understood from the following diagrams, where S represents the position of the sun, M, M′, of the moon; E, of the earth, with its covering of waters. Fig. 7 showing the positions in which *spring-tides* are formed; fig. 8, that in which *neap-tides* are the result. The position of the moon when new, is shown in M fig. 7; full moon at M′.

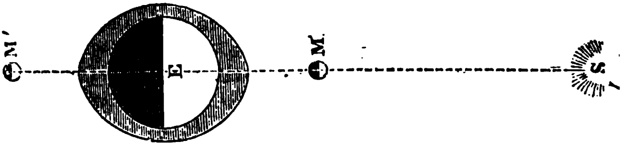

FIG. 7. SPRING TIDES.

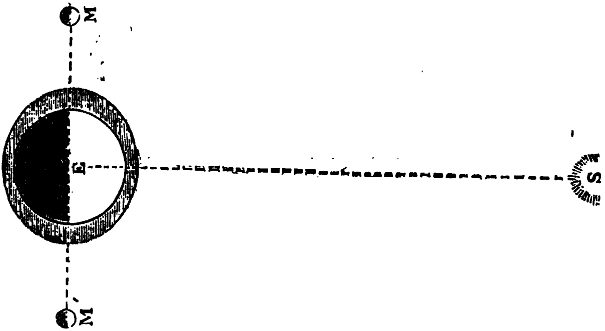

FIG. 8. NEAP TIDES.

(*e*) *Establishment.*—The time of high water is not exactly the time of the moon's transit over the meridian; for the waters do not at once obey the force of the attracting bodies, but require, as it were, pulling for some little time before they move; hence it happens the tide follows the moon at some distance, high water occuring two or three hours after the moon has passed over the place. This interval of time between the passage of the moon over a place on the day of full or new moon, and the actual time of high water at the place, is called *the establishment of the place, or port.*

(*f*) *Priming and Lagging.*—Another variation in the tides is caused by the relative position of the sun and moon at different times. In the first and third quarters the moon is to the east of the sun, and the solar tide being to the west, high water happens earlier than if the moon alone caused the tide: this is called the *priming* of the tide. In the second and fourth quarters the reverse of this happens; and the effect of the solar tide being behind the lunar tide, high water occurs later than it would otherwise: this is known as the *lagging* of the tide. There are other minor variations in the tides, which need not be entered upon in this place. Sufficient has been given to afford a good general idea of the phenomena of the tides.

(*g*) *Formation of the Tide-Wave.*—We have now described what would be the general character of the tides, if the entire earth were covered with water; and we must proceed to give some account of them as they actually occur upon the globe. The effect of the land in modifying the tides is much greater than its effect upon the ocean currents; indeed the great tide-wave following the moon in its course, and sweeping round the earth daily, never is formed, so divided are the waters. What may be called a *partial* tide, is formed on the eastern and destroyed or deflected on the western shore of each ocean; and we must go far away into the Southern Ocean, between lat. 30° and 70° S., to find sufficient expanse for the production of an unimpeded tide-wave; and it must constantly be borne in mind that *it is from this southern tide that all the tides* of the Indian and

Atlantic Oceans, and, of course, of our own seas also, are formed.

(*h*) *Co-tidal*[1] *Lines.*—The progress of the tide-wave is traced by means of what are called *Co-tidal Lines*, which are thus formed:—Take any place, and find the time of high water on the day of full or new moon; that is, find the *establishment* of the place. Now find a number of points at which it is high water at the same time; or in other words, where the *establishment* is the same. Draw a line through these points, and it will indicate the summit of the tide-wave at that time. Such a line is called a *Co-tidal* line. If we trace a line through the points where the establishment is an hour later, we produce a second *Co-tidal* line; and if we do this consecutively, hour by hour, we shall have mapped out a series of co-tidal lines. From such a map or chart it appears (1) that the tide-wave, which, if unimpeded, would pass entirely round the globe in twenty-four hours, requires thirty-six hours to perform its circuit, even in the free Southern Ocean. (2) We can see what time has elapsed between the formation of the tide-wave, and its arrival at any given place; that is, a chart of co-tidal lines shows us the *age* of a tide. The tide is twelve hours old off the south of Australia; in twenty-four hours, it has reached Hindostan and the Cape of Good Hope. Off the North of Africa it is thirty-six hours old; and off London forty-eight hours, or two days old. (3) This *age* of the tide makes clear a very important fact, namely, that the tides, say, on our own shores, are due, not to the direct action of the sun and moon at the place; but to their action in the Southern Ocean. (4) A chart of co-tidal lines enables us to estimate the velocity of the tide-wave. Its average speed, if unimpeded, would be about 900 geographical miles per hour; its actual velocity is much less. In the Atlantic, as we have seen (p. 63), it is about 500 miles per hour; from the South of Ireland to the North of Scotland, the rate is about 160 miles an hour; on the east coast of Britain it is less, and continually diminishes, being about 60 miles off Scotland, and thirty miles an hour off the mouth of the Thames. (5) The tide-wave necessarily moves with the greatest velocity where the depth is greatest (p. 62). The result is, that while towards the coast the tide is, held back, in the open sea it progresses much more freely; so that the shape of the wave is a curved line, convex towards the open sea or deep water. This is very apparent in the Atlantic Ocean, where the co-tidal line along the coast is seen far to the south, of the same line in deep water. Where the depth becomes less, the tide travels slower, and the co-tidal lines appear to crowd together. This is seen to take place off the islands of St. Helena and Ascension, off the Bermudas, and again off the Azores, etc. From this it follows that some idea of the *comparative* depth of the ocean may be formed by a study of co-tidal lines; and the following simple rules may be given for the guidance of the student:

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[1] L., *co*, together, at the same time.

Rule I. The greater the distance which separates the co-tidal lines, the greater the depth of water. And necessarily, the closer the lines are crowded together, the shallower the water.

Rule II. In any co-tidal line, the curves mark the varying depth; the convexity of the curve showing the deeper water.

(*i*) *Progress of the Tide-wave.* The tide-wave, we have seen, is found in the Southern Ocean, between the latitudes of 30° and 70°; and passing in its westerly course the island of Australia, it rapidly curves into the Indian Ocean, across which it sweeps in six hours; then passing the Cape of Good Hope, it bends gradually more and more to the north, travelling steadily on with a varying speed of from 500 to 700 miles an hour, and at length reaches our shores. Still continuing its northerly course, it enters the Arctic Ocean, finally reaching the pole. It may even influence the tides of the Pacific Ocean, by passing through Behring's Straits.

Off our own coast, it divides into three branches. The principal branch passes along the western shores of Ireland and Scotland; and bending round the Shetland Isles, flows southward down the eastern coast of Britain, meeting a second branch, which has travelled up the English Channel, near Dover. This second branch, which arrives off Cornwall about five, reaches Dover about eleven, where it meets the first branch as above stated. But the tide which it thus meets is not of the same age as itself, but is the tide which set out twelve hours earlier; the branch corresponding to itself being then on the north-east coast of Scotland. The third branch runs up the St. George's Channel, and forms the enormous tides of that coast.

In the Pacific Ocean, the tide-waves travel from east to west, and are very small; rising only two feet in the Sandwich Islands. They are but imperfectly worked out.

(*k*) *Bores*. When, as in great bays and narrow channels, the waves are crowded together, they become heaped upon one another; and a sudden rise of the water takes place, rolling in as a great wave. This is called a *bore*. Examples are found in the Hooghly River, and the Amazon, where the bores are of such fearful magnitude and force, as to devastate the entire surrounding country. On our own coast, the Bristol Channel affords an instance of a bore; the spring-tides at Chepstow, rising to nearly 40 feet; and a bore 8 or 9 feet high rushes up the river. In the Wash, the first waves of the tide sweep with great violence, and are well known, and are called the *Aigre* or *Hygre*.[1] In the Bay of Fundy, the tide rises 50 feet. The rivers Garonne in France, and Tsientang in China, are other instances of bores.

In some places, from local causes, curious variations in the tides occur; thus at Tonquin, there is only one tide daily; and at Singapore the same thing occurs.

3. **Earthquake Waves.**—These waves are the result of sudden changes in the sea-bed and coast-line, caused by earthquake convulsions. They differ from wind-waves, chiefly in being much larger. The great wave caused by the earthquake in Japan, which was 217 miles broad, has already been alluded to. The great earthquake, which in 1755 destroyed Lisbon, formed a wave which swept across the Atlantic; it was 60 feet in height at its commencement, and at the island of Madeira caused a rise of 12 feet in the water.

8. **Ice.**—The phenomena of Ice will be found described in the article on Ice.

CHAPTER IV.

INLAND WATERS.

Circulation of the Waters.—We may look upon the ocean as the source from which all other waters are derived. From its surface the sun's heat lifts daily a certain amount of moisture as invisible vapour; this process is called *evaporation*.[2] The moisture so abstracted is dispersed over the globe by the winds, and is re-deposited as rain, snow, and dew; part of it being returned directly into the sea, the rest falling upon the land. Of that which falls upon the land, part forms into streams, which joining together become rivers, and flow into the sea, and part soaks into the ground, some of it re-appearing as springs, which help to swell, and in some cases form, the streams, and some finding its way deep down the earth. Thus we see a constant *interchange*[1] is kept up between the water of the land surface and the water of the ocean. If it were not so, the land would speedily become parched into a desert by the loss of its water carried off by rivers; and the sea, raised above its level by the addition of this water, would wash the shores of arid lands upon which no vegetation could flourish, no animal exist. The atmosphere is the great highway along which the moisture is carried to replenish the land, and the winds are the vehicles by which it is conveyed.

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[1] An old Danish word.

[2] L., *e*, off, and *vapor*, vapour; to fly off in vapour.

Divisions.—We will consider this water as we find it upon the surface, leaving for a future chapter (Chap. V.) the examination of the manner in which it is transferred from the sea to the land. The subject naturally divides itself into three sections, (*a*) *Springs*, (*b*) *Rivers*, (*c*) *Lakes*.

A. SPRINGS.

Classification.—We have said that part of the water that soaks into the land is again returned to the surface as springs. But it must not be thought that in all cases the water re-appears at or near the spot upon which it has fallen; sometimes indeed it does so, but in by far the greater number of cases it has been conveyed by subterranean channels long distances, and in certain instances only appears after having found its way deep into the crust of the earth, there to become heated and charged with various substances, before it is forced back again to the surface. Under one or other of these conditions every spring occurs, and it seems to us to be a convenient way of classifying springs according to their origin. Three kinds of springs exist, under this view, namely:—

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[1] L., *inter*, between. A change between two or more objects or persons.

1. *Land Springs,* or such as give back their water to the surface at or near the place where it fell.

2. *Transtratic*[1] *Springs,* or such as return their water to the surface at points more or less distant from the source whence it was derived. Such water having been conveyed or transmitted through porous beds of rock.

3. *Deep-seated Springs,* or such as transfer water to the surface from great depths, all connection with the original source of the water being lost.

1. **Land** (or *Surface*) **Springs.**—These occur in situations where the bed of rock[2] at the surface is pervious[3] to water, and is underlaid by an impervious bed. For example, the ordinary wells in London are supplied by land-springs, the upper bed being gravel, the lower bed clay. Rain falling upon the surface soaks through the gravel, but is prevented from passing away downwards by the impervious clay; the gravel becomes more or less full of water, and a well or pond dug into it fills with water to a height somewhat below the point to which the gravel is saturated. The supply of such springs depends almost directly upon the rainfall of the immediate district, and is therefore liable to suffer in dry sea-

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[1] L., *trans*, through, and *stratum*, a layer or bed.

[2] Geologists call all materials *rocks* which form beds or portions of the earth's crust; thus, clay and gravel are rock, just as much as granite is.

[3] L., *per*, through, and *via*, a way. That which can be passed through. *Impervious* (*im* or *in*, not) is the reverse.

sons. The water is also very apt to be tainted with refuse matter from the sewers, where a proper drainage system is not carried out.

2. **Transtratic Springs.**—This class of springs I have so named because the water they send forth is not that which has fallen immediately above, but has soaked into the rock, at some other point, and *has run through it* in the direction of the slope until the bed has again reached the surface. This will be better understood by reference to the following diagram (fig. 9), wherein certain beds of rock are seen as if cut through; the irregular line being the surface of the ground. Let A B represent a water-bearing bed, and C C′ impervious beds. Rain falling anywhere upon A will soak into the rock, and will work downwards till it is checked by the impervious bed C. The tendency of the water still being in a downward direction, it will gradually flow down through the pervious bed and will burst forth at B as a spring. The water appearing at B, having originally fallen at A, which may be near or many miles distant. This gives us one of the simplest examples of such springs; much more complicated cases occur when the beds are bent and shattered as they often are, but an examination of such facts would lead us too much into the realms of geology.

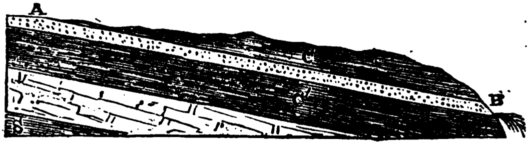

FIG. 9.

So far the origin of these springs seems clear enough; but a difficulty arises when we consider that springs only appear at certain spots, and *not everywhere* *along the junction of a pervious with an impervious bed,* as they might be expected to do. This is most likely owing to inequalities in the surface of the underlying bed which allow the water to run into channels, and form underground streams and reservoirs. We know that when water falls upon a sloping surface it does not spread equally over the surface in a sheet, but takes advantage of any little inequality of the surface to form channels down which it chiefly runs. Much the same thing seems to go on underground and out of sight, and on this supposition we can readily see why springs issue only at intervals along the junction of the beds.

Some of these springs are *intermittent,*[1] that is to say, they stop for a while and then burst forth afresh. This seems to be owing to the water collecting in pools or reservoirs in the rock, and finding its way out through curved passages which act as *syphons.*[2] When the water in the reservoir rises above the bend of the syphon, it begins to flow and continues to do so till the level of the water is reduced below the bend, when it ceases to flow, and allows the reservoir to fill again. Sometimes this filling and emptying takes place very rapidly: a well-known spring at Colmar, in France, rises and falls eight times within the hour; in other cases the intervals are much longer, weeks and even months intervening between the two states.

Artesian Wells belong to this class of transtratic springs. They are borings, usually deep, up which the water rises naturally. In the London district several have been put down, and have proved very successful. The explanation of such wells must always be sought in the peculiar arrangement of the water-bearing beds. Thus, in the case of the wells just mentioned, the water-bearing rock is the chalk, which comes to the surface, both north and south of London, in the North and South Downs; and as it is found at a depth of 300 feet below that city, it evidently lies in the form of a trough, which has hence been called the London basin. The water coming in from both sides collects under London at a great pressure, and when the bed is tapped by a boring, it is forced up by that pressure.

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[1] L., *inter*, between, and *mitto*, to cause to send. Occurring at intervals.

[2] Gr., *siphon*, a hollow body, as a reed. A bent tube, such as is used to draw beer from a barrel.

Another arrangement of beds which gives rise to artesian wells, is such as is found in South Lincolnshire, where, at Bourn, several have been made. One especially was formed last year (1870) to obtain a supply of water for Spalding, a town ten miles distant. The water-bearing bed in this case is a limestone of considerable thickness, and covering a large area at its *outcrop.*[1] It slopes down in the direction of Bourn, and grows much thinner in the direction of its slope. At Bourn it is 90 feet below the surface. The water flowing down through the rock becomes pent up as the bed grows thinner, and when it is pierced, rises with such force as to damage the boring apparatus.

Most of the springs which appear at the surface belong to this class of transtratic springs, but their varieties are too great to allow of an examination in this place.

In districts where limestone rocks abound, large cavities, and indeed considerable rivers, occur underground, caused by the dissolving away of the limestone by the water. Some of the springs in such regions contain such a quantity of lime as to deposit it as a thick coating upon any bodies placed in the waters. Such springs are known as *petrifying*[1] springs, a very misleading term, as they do not *petrify*, but only *coat* the substances with rocky matter.

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[1] Geologists call the portion of a bed which lies at the surface the "outcrop."

Petroleum[2] is found in the waters of many springs, as in Auvergne; but in some cases the oil itself rises in springs, as in the case of the celebrated oil-wells of North America, which yield over a hundred million gallons a year. In Trinidad, there is an enormous supply, forming the Pitch Lake. Other springs of petroleum, or *bitumen*,[3] are known, as at Baku on the Caspian, in Zante, and in Palestine, etc. The substance is derived from the natural distillation of beds of vegetable matter, and perhaps animal tissue helps in some cases to form it. Petroleum is found in rocks of all ages, but "a large number of the oil-wells of the United States . . . are in Devonian rocks" (*Lyell*).

3. **Deep-seated Springs** are such as well up from the depths of the earth, finding their way through crevices in the rocks. They usually contain a considerable quantity of foreign matter, which has given to some of them a world-wide celebrity for medicinal properties. Many of them have a very high temperature, in which case they are called *thermal*[4] springs; those which contain much foreign matter are named *mineral* springs, and they are said to be

(*a*) *Saline*,[5] when they contain salt; or, when extremely salt, *brine*-springs. As at Cheltenham and Epsom, Northwich (brine).

(*b*) *Calcareous*,[6] when they contain much lime. As in Auvergne and Italy.

(*c*) *Chalybeate*,[7] or *Ferruginous*,[8] when iron is present. As at Tunbridge Wells and Brighton.

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[1] L., *petra*, a rock, and *facio*, to make. [2] L., *petra*, rock, and *oleum*, oil. [3] L., *bitumen*. Bitumen occurs under various forms : *petroleum* is a liquid, *asphalt* a solid, variety. [4] Gr., *thermos*, hot. [5] L., *salinus*, salt. [6] L. calx, lime. [7] Gr., *chalybos*, *iron*. [8] L., *ferrum*, iron.

(*d*) *Silicious*,[1] when *silica*, or flint, exists in them, as in the Geysers, Azores, etc.

(*e*) *Sulphurous*, when sulphur occurs, as at Harrowgate.

(*f*) *Carbonated*, when carbonic acid is found, as in Auvergne.

Saline, chalybeate, sulphurous, and carbonated waters are much drunk as medicines, and the places where they occur are called *Spas*, from *Spa*, in Germany, where celebrated mineral springs exist. *Selters*, also in Germany, is the town which gives its name to the celebrated Seltzer water, in which such a large trade is now carried on. Many other substances occur in these mineral springs, interesting only to the chemist and the geologist; but *iodine* and *bromine* may be mentioned here as possessing valuable medicinal properties. The largest quantity known to occur in any spring is at Woodhall Spa, near Horncastle. This spring was discovered in making a hopeless boring for coal.

Origin of the Constituents of Mineral Waters.—It is a very suggestive fact that the mineral matters dissolved in these waters are the same as those which escape as gas in volcanic regions; this, and their frequent thermal character, give to these waters a highly probable connection with volcanic agency. Moreover, they occur most frequently in districts which are now, or have recently been, the seat of volcanic action. Even when far removed from such areas they are found in nearly every case to correspond with lines or centres of disturbance in the rocks. It may also be taken as a general rule, that thermal springs become less frequent and lower in temperature the further we go from volcanic districts. The immense quantity of water which must penetrate into the earth to supply so vast a scheme must be derived, as has been before hinted, from that portion of the surface water which is neither evaporated back into the air, nor carried off by streams, nor returned to the surface as land, or transtratic springs; and if, as is certain, large volumes of water can thus penetrate from the partially moist surface, how much more must be supplied directly from the bed of the ocean! In support of this latter opinion, it is to be observed that salt is one of the most common constituents of mineral waters, and nitrogen gas (which forms the greater portion of air) bubbles up through them, disengaged most probably from the air carried down into the earth with the water.

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[1] L., *silex*, flint.

Circulation of Water in the Earth.—If this idea of the origin of the waters of deep-seated springs be true, there must be a circulation of waters in the solid earth rivalling in magnitude that which takes place through the air, and the effect upon the rocks beneath must be as great as that exercised by running water upon the surface.

Conclusion.—From what has been said above, it will be gathered that the term *spring*, is applied to any source of water within the earth, no matter whether it appears at the surface or not; for it is plain that the water in the rocks has been derived in the same manner as that which issues forth at the surface.

It must also be borne in mind that all spring-water contains *some* mineral matter, or it would be "soft" and not "hard;" but the term "mineral water" is only applied to such as contains an unusually large quantity.

B. RIVERS.

Origin.—The greater number of rivers take their rise from *the snows* and glaciers of the mountains, some are fed by springs, and others find their origin in lakes. At first they are small streams, but as they travel onwards they are increased by the junction of other streams, till from tiny rivulets they become full sized rivers.

Description of a river.—To describe, even shortly, the rivers of the earth would occupy more space than we can devote to the subject; we will, instead, describe an imaginary river, explaining all the terms as we proceed.

One of the principal purposes which rivers serve is the drainage of the surface of the land. The area drained by a river and the streams it receives, is called the *basin* of the river. The parting between two river-basins is called the *water-shed;* but this term is better applied to the area which sheds the water, the term *water-parting* being a more appropriate designation for the line of division between two water-sheds.

Now let us start with our river. We will suppose it to be fed by the snows of a lofty mountain-range, and to flow to the sea. The place where it originates is called the *source;* the place where it enters the sea is its *mouth;* the direction it takes is its *course.* As we stand facing the mouth, that is, looking in the direction of the current, the bank on the right hand is called the *right bank,* and the opposite one the *left bank.* The depression in which the river runs is the *channel,* and the bottom of the channel is the *bed.*

At first the stream runs rapidly down the mountain slope, carrying pebbles and sand in its course, which, perpetually grinding along the sides and bottom of the channel, gradually but surely deepen it. Reaching very broken ground, and dashing over a terrace of rock, it descends as a *waterfall* into the region below; here, pent up within narrower limits than before, it rushes with great speed, forming *rapids*, and meeting with several ledges of rock, one under the other, it falls over them, and appears as seen from below, like a series of waterfalls one above the other; such a fall is called a *cascade*.[1] Thus it flows on, rapid, shallow, and quite unfitted for navigation, until it leaves behind it the mountain region, and enters upon the less abrupt country at the base. This first portion of the river is called the *upper course*.

The *middle course*, which we will now describe, forms the chief portion of the river. Here, large streams, rivalling the river in size, join it, and are called *tributaries*, because they contribute their water to the main stream. A singular fact now comes to light; the river, though containing double the water it had before, does not sensibly increase in width, nay it may (as when the Missouri joins the Mississippi) even diminish, but the extra water is easily carried off by the deepening of the channel, and the quickening of the speed. The point where two streams join is called the *confluence*.[2] Throughout this middle course the river bends and winds about, its current is steady, its channel broad and deep, and it is navigable.

Its *lower course* is the portion connected with its mouth. No important tributaries fall into it, but the tide sweeps up it from the sea. At the mouth, the mud and sand and gravel it has been collecting from the first, may be carried out to sea and spread along the bottom; or it may accumulate as a bank or *bar* opposite the mouth; or, checked by the ocean, it may fall within the *estuary*,[3] as the mouth is called, if it is wide, and gradually form a triangular shaped island, the point being directed up-stream; the island so formed is called a *delta*.[1]

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[1] Fr., *cascade*, a waterfall. [2] L., *con*, together, and *fluo*, to flow. [3] L., *æstuo*, to boil up. So called from the *boiilng* or *foaming* sometimes arising when the tide and river-current meet.

Additional Observations on Rivers. (*a*) *Source.* The sources of rivers flowing in opposite directions may be in the same group of lakes, as in the rivers of Maine and Canada; in some of these one river will pass by the source of another running in an opposite direction, that is they *interlock*. Again, the sources of rivers flowing in opposite directions, are sometimes so near together, that boats and their cargoes are carried from one to the other; this constitutes a *portage*,[2] and is an important feature in some districts of North America. These examples show how much better the term *water-parting* would agree with the facts than the word *water-shed*, and it is to be hoped it will come more generally into use. The water-parting need not necessarily run along a mountain ridge. In some cases, as above shown, it has to be drawn arbitrarily[3] through a series of swamps and lakes. One case at least is known where a lake has one outlet conveying water eastwards, and another carrying it to the west; this occurs in the Rocky Mountains. In North Europe, the water-parting is determined by a slight swelling in the plain.

(*b*) *Union of Rivers.*—The basins of rivers flowing in the same general direction are sometimes separated in part of their course by such slight elevations, that branches flow from the one to the other. The best example of this kind is in South America, where the *Cassiquaire* unites the *Orinoco* with a branch of the *Amazon* (the *Rio Negro*). Other instances occur, especially in the East, the *Ganges* and the *Brahmapootra* being a good case in point. In our own country, the rivers *Ouse*, *Welland*, and *Nene*, connect by many branches in the low lands of the fen district. When the mouths of rivers lie near together, they often unite by their deltas: the union of the *Rhine*, the *Meuse*, and the *Scheldt* being an example.

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[1] From the shape of the Greek letter *delta*, Δ, d.

[2] Fr., from the Latin, *portare*, to carry.

[3] L., *arbiter*, a judge. *Depending on the judgment or will.*

(*c*) *Deltas.*—Deltas are occasionally of large extent, and furnish some of the most fertile spots on the earth's surface. Egypt, said Herodotus, is the gift of the Nile; and this saying, often in the mouths of the ancient Egyptian, is no less true to-day. Lower Egypt is nothing more than the delta of the Nile. The fine, rich mud from the interior of Abyssinia, is borne down by the river and deposited upon the desert sands of Africa, converting one of the most sterile wildernesses into one of the most fertile plains. The delta commences ninety miles from the sea, and its base along the coast has a total length of more than 200 miles. Time was when this space formed a great estuary, but the thin, almost imperceptible deposit of the Nile has, in the course of ages, converted it into land. It is calculated, from observations made at Memphis, that the delta is between 13,000 and 14,000 years old.

The Mississippi delta covers 12,300 square miles, and its average thickness is estimated at 500 feet. It is continually growing out into the Gulf of Mexico, in the shape of a huge fan.

The delta of the Ganges and Brahmapootra is perhaps the largest in the world. It covers 22,000 square miles, and is of great thickness. So enormous is the quantity of matter carried down by this river that "if a fleet of more than 80 Indiamen, each freighted with about 1400 tons weight of mud, were to sail down the river every hour of every day and night for four months continuously, they would only transport from the higher country to the sea, a mass of solid matter equal to that borne down by the Ganges during the flood season" (*Lyell*).

The *Amazons* has another enormous delta, but we cannot here describe it. All rivers do not possess deltas, the material in many cases being carried directly out to sea.

(*d*) *Water of Rivers.*—River water, like all other water on the surface of the earth, contains a quantity of solid matter *dissolved* in it. This is over and above that described before, as going to form deltas, etc., and though not so great in quantity, is still very considerable. The principal materials so dissolved are *carbonate* and *sulphate of lime* and common salt. It is the presence of these which makes the water of rivers, like that of springs and lakes, hard. So small a river as the Thames, carries annually into the sea 33½ tons of solid matter dissolved in its water; and the Rhine has been calculated to supply enough carbonate of lime in this manner to form the shells of 332 millions of oysters!

(*e*) *Descent of Rivers.*—The slope down which rivers flow, varies in different portions of the same river. The upper course has the most rapid fall, and as the stream proceeds on its journey, the slope becomes less and less, until near the mouth it is often nothing. Mr. Tylor has recently shown that the course of rivers either actually is, or at any rate closely approximates to, a *parabolic* curve, and that if the heights of three points in a river's course are known, the height of any other point can be determined.

If the slope be 1 in 200, the stream is not navigable; above that slope rapids and cascades are formed. The Rhone, a very rapid river, has a slope of 1 in 2624; the Volga falls 4 feet in the mile on the average; the Danube 2 feet in the same space, and the Nile one foot.

(*f*) *Floods of Rivers.*—Most rivers are subject to a periodical increase in the amount of water they convey. The seasons in which these floodings take place vary according to (1) the latitude of the river, (2) *the nature of* the source from which it rises, and (3) from the direction of its course. In northern districts spring and early summer, when the ice breaks up and the snows thaw, are the times of flood. But in temperate regions, especially where there are no snow-clad ranges to swell the streams with their melting covering, flood-time varies with the season: a wet season being fruitful, and a dry season barren, in floods. The rivers of the high latitudes which flow northwards, as in North America and Russia, on the breaking up of winter are swollen into devastating torrents; and when, as often happens, the upper course of the river thaws before the ice-blocked mouth begins to melt, the water, finding no channel, flows over the ice, and lays under water whole districts.

In tropical countries, where violent rains fall within a limited space of time, the rivers rise with wonderful rapidity, overflowing their banks, and converting the neighbouring lands into sheets of water. In the Ganges the flood season is from June to September, and during these four months very nearly ten times as much water is discharged as during the remaining eight months. The Mississippi lies within the north temperate zone, and is flooded in the spring-time, when immense numbers of trees are torn up and carried down the stream; these accumulate in certain spots, and form *rafts;* one of them, known as the raft of Atchafalaya, was "no less than 10 miles in length, 220 yards wide, and eight feet deep." The Orinoco has a flood season, marked by great regularity: the waters commence rising about the 25th of March, and begin to decrease about the 25th of August; immense districts are laid under water during this season. The Amazon, lying on the south of the equator, has its season of inundation at a different time from the Orinoco, beginning to rise in November, and attaining its greatest height early in June. Great tracts of the Matto, or forest region of the Amazon, are covered by its floods during this season. The Nile, whose inundation alone saves Egypt from barrenness, owes its floods to the rains of Ethiopia, but much obscurity still hangs over the subject. At Cairo, it begins to rise in June, and goes on increasing till October; after which it subsides, and reaches its lowest point in April and May, in which latter month we have walked across it a few miles above Cairo. The inundation waters are conveyed over the country by canals, and allowed to flow over the fields, depositing a thin layer of rich mud.

(*g*) *Varieties of Rivers.*—Rivers which flow into the sea have been called *oceanic rivers*, to distinguish them from those which discharge their waters into lakes not communicating with the sea, and which are known as *continental rivers.* There is, of course, no difference between these two classes (if we except the influence which the tide has upon some of the oceanic rivers); the fact of their pouring their water into the sea, or not, being a pure accident.

(*h*) *Tidal Rivers.*—A few words must be said about those oceanic rivers up which the tide runs, and which are hence known as *tidal rivers.* The mouths of these rivers are like arms of the sea, through which a current of fresh water flows. Their tidal character is often of vast commercial importance, allowing the navigation of rivers to an extent that would be impossible without it. London owes much of its greatness to this circumstance, for if the tidal flow of the Thames could be suddenly destroyed, the splendid vessels lying in her miles of docks must there remain until decay reduced their frames to dust, and the vast fleets bound for her haven, could never reach it, but must convey their precious stores elsewhere. The tide in this river is felt 70 miles from the sea.

In some of the large rivers, the tide reaches an immense distance; thus in the Amazon it is felt 576 miles from the mouth; in the Orinoco, 255 miles; and in the Yang-tse-Kiang, 400 miles.

(*i*) *Steppe Rivers.*—One variety of continental rivers needs a passing notice. Some considerable streams that enter the porous soil of deserts and similar regions become literally sopped up, and dwindle away completely. Many such cases being known in the steppes of Asia, they have been called *steppe rivers.* South America, the North American deserts, and Australia, afford many such phenomena. In our own country, the River Welland is sometimes a fine stream at Stamford, and is almost entirely absorbed in passing through the dry, porous soil of the fens; this was the case last summer (1870).

Distribution.—We can only allude very briefly to the distribution of rivers. The best way to consider the subject, is to group together those rivers which discharge into the same ocean or lake. In this way we find, according to Professor Ansted's estimate, that nearly ten millions of square miles drain into the Atlantic, over five and a half millions into the Pacific, five and a quarter millions into the Arctic Ocean, and over one and a quarter millions discharge into the lake basins of the interior of Asia.

The principal rivers of Europe correspond roughly with those of Asia. In the north, the Dvina, Mezen, and Petchora of Europe, answer to the Obi, Jenesei, and Lena. In the south, the Ebro, Rhone, Po, Danube, Dnieper, Don, and Volga, are represented in Asia by the Euphrates, Indus, Ganges, Choe Kiang, Yang-tse-Kiang, Hwang Ho, and Amoor. This comparison must be understood as nothing more than a rough coincidence; but it may be useful in helping to fix the position of the chief rivers in the mind.

In North America, the three principal rivers rise in the centre of the continent, but flow in different directions, the Mackenzie running north, the Mississippi flowing south, and the St. Lawrence journeying eastward. In South America, there are also three main streams: the Orinoco, the Amazons, and the Parana or La Plata; the two first pursue an easterly course, the last runs in a southerly direction.

The length of a few of the main rivers of the globe, are given in the following table, together with the names of the countries through which they chiefly run, and the area of their basins in square miles.

Name of River.	Length.	Area of Basin.	Country.
Amazons	4,000	2,500,000	Brazil.
Mississippi and Missouri	4,265	1,500,000	United States.
Obi	2,400	1,500,000	Siberia.
La Plata	2,700	1,250,000	South America.
Jenesei	2,800	1,000,000	Siberia.
Lena	2,400	800,000	,,
Amoor	2,750	780,000	Eastern Asia.
Yang-tse-Kiang .	3,300	727,000	China.
Hwang-Ho . . .	2,280	720,000	,,
Mackenzie . . .	900	600,000 ?	British America.
Ganges	1,700	580,000	India.
Brahmapootra . .	1,680		
Indus	1,960	500,000	,,
Irrawady. . . .	1,250	440,000	,,
Volga	2,400	400,000	Russia.
St. Lawrence . .	2,000	300,000	Canada.
Orinoco	1,600	300,000	Venezuela.
Danube	1,496	234,080	Austria and Turkey.
Dnieper	623	226,000	Russia.
Rhine	700	87,000	Netherlands, Prussia, &c.
Petchora	1,000	65,000 ?	Russia.
Dvina	330	44,500 ?	,,
Thames	240	6,500	England.
Nile	3,000 ?	unknown	Africa.
Zambesi	1,000 ?	,,	,,
Niger	1,000 ?	,,	,,

C. LAKES.

Definition and Classification of Lakes.—Lakes are sheets of water formed in depressions of the earth's surface. When very large, they are called *inland seas*, as the Caspian Sea; small mountain lakes go by the name of *tarns*.

Lakes fall naturally into two divisions, according to their mode of origin—(1) those which have once formed part of the sea, but have been cut off by the elevation of a portion of the sea-bed; and (2) depressions in the land-surface which receive a portion of the drainage. The *Caspian*, and *Sea of Aral* are instances of the first class; the great lakes of America, our own, and indeed most other lakes, belong to the second class. This classification is founded upon geological inferences, and may thence be called the *geological* classification of lakes.

Again, lakes may be classified according to the mode in which they receive and discharge their waters, quite irrespectively of their origin. In this case we have a *geographical* classification. This gives us four distinct classes; namely,—

(*a*) Lakes which receive and discharge rivers. These are often only expansions of the stream. The greater number of lakes come under this section. Their waters are *always* fresh. *Lake Superior* is an example.

(*b*) Lakes which receive no streams, but discharge their water by streams. The supply is kept up by springs rising from the bottom. Their waters are *always* fresh. The river Volga has its source in a lake of this kind in the Valdai Hills.

(*c*) Lakes which receive, but do not discharge rivers. They depend for the discharge of their extra water upon evaporation, and sometimes, perhaps, subterranean passages. Their waters are *often salt.* The *Caspian* is an instance in which the waters are quite salt; *Lake Van*, in Armenia, is brackish; *Lake Balkash*, in Western Asia, is an example containing fresh water.

(*d*) Lakes which neither receive streams nor possess any visible outlet. These are small in extent. *Lake Albano*, near Rome, is of this kind.

This mode of classifying lakes, though most obvious, is not so good as the geological division, for it groups together lakes which have really but little in common: as the Caspian, which has once formed part of the ocean, and was originally salt, and the Great Salt Lake, which has never been continuous with the ocean, but is salt because its excess of water is discharged by evaporation, leaving the salts behind.

Conditions under which Lakes exist.—Into the origin of the depressions in which lakes occur, it is the province of geology to inquire; some being believed to arise from partial sinkings of the land, and others from the grinding power of glaciers. But into the conditions of climate, etc., under which lakes are found, and to which they owe their existence and character, it is our duty to examine.

Starting then with the fact that depressions suitable for the accumulation of water do exist, we find lakes dependent for their character upon two features—

1. The proportion which the supply bears to the evaporation.
2. The height of the lowest portion of the rim or edge of the cavity.

Let us take the case of evaporation first. Evaporation takes place from the surface of all water, and the amount of water thus removed is dependent, everywhere, *upon the extent of the surface exposed*, and not upon the amount of the water. A very deep lake, with only a small surface, may contain as much water, or even more, than a shallow one covering a much greater surface; but in the former case, the loss by evaporation is slight, and in the latter very great.

Suppose a stream to flow into a depression, the water will continue to rise, and its surface to increase, until the evaporation equals the supply, after which it will remain steady. But if, before this state is attained, the water reaches the lowest portion of the depression, it will overflow. Hence we may conclude generally—(1) That in lakes having no outlet, the basin or depression is so large that evaporation becomes equal to the supply before the basin is filled; and (2) that in lakes having an outlet, the water supplied is in excess of that removed by evaporation. From this it appears that, with a given quantity of water as supply, a lake of only a certain size can be formed; or, in other words, no matter how large the basin be, the river can only fill it to a certain height, even if it flows continually into it.

Hitherto we have been considering the supply as constant at all seasons of the year, and the evaporation to be equally steady; but this is not by any means always the case. Indeed, in hot countries, it often happens that when the supply is least, the evaporation is greatest. In this case the lake is constantly altering in size, increasing in the wet season, and diminishing in the dry, hot season. To such an extent does this take place, that large lakes, as Xarayes, on the river Paraguay, have been alternately drawn on, and effaced from, the maps of South America. Lake Tchad, in Africa, is another instance of this character; and the Australian lakes, Torrens, Gardner, and Eyre, afford other examples of this peculiar class, which are sometimes so large as to rank among the great lakes of the world, and at others have dwindled into a series of shallow, stagnant pools.

Salt Lakes.—The mode of origin of certain salt lakes has been alluded to in speaking of the geological classification of lakes; namely, those which, at one time forming arms of the sea, have been cut off by the elevation of a portion of the sea-bed. The largest example is that known as the Aralo-Caspian area, from its containing the Caspian Sea and the

Lake of Aral. This area seems to have been subject to very irregular movements of the earth's crust. There is evidence of the land between these two sheets of water having formerly stood at a lower elevation than at present, and been covered with water. It appears, too, that the areas, both of Aral and the Caspian, are decreasing yearly. This is not altogether due to the evaporation being in excess of the supply, but also in some measure to a diminution in the supply, the rivers pouring in less water than formerly, owing to the increase of cultivation, as will be explained hereafter, and to the loss by irrigation canals.

Another class of salt lakes is very different from that above described. These have never formed a portion of the ocean, but are basins receiving their supply from rivers. In all cases they belong to the third section in the geographical classification, or such as have no outlet.

The water of all rivers contains salt, which is usually carried into the sea; but as the lakes we are now considering have no outlet for the water, the salt is left behind within the lake, evaporation carrying off nothing but pure water. This process continuing for ages, the lake growing each day salter, becomes at first brackish, and at length quite salt. Many of the lakes so formed are salter than the ocean. The saltest are Lake Eltonsk,[1] in Russia, Lake Urimiyeh, in Persia, and the Dead Sea[2] or Lake Asphaltites. If such lakes become dried up, as many have, a deposit of salt is left behind.

Area and Altitude.—Prof. Ansted has estimated that all the fresh water surfaces on the globe do not exceed 500,000 square miles, and that the area of the salt lakes is somewhat less. This gives under a million miles of land-surface covered by fresh water and salt lakes.

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[1] Contains 29·18 per cent.

[2] Contains 26·24 per cent.

The area of individual lakes of course varies from a few yards to several thousand miles. A few of the largest will be here noticed. The *Caspian Sea* is the largest expanse of inland water known; its area is 140,000 square miles, or nearly equal to that of Great Britain and Ireland: it is 84 feet below the level of the Black Sea. The *Lake of Aral*, in the same region, is 23,300 square miles, and is 33 feet above the Black Sea. Next in size to the Caspian is *Lake Superior*, with an area of 32,000 square miles, 857 feet above the Atlantic; this, with the attendant lakes, *Michigan*, *Huron*, *Erie*, and *Ontario*, covers an area of 93,000 square miles. Between the two last named occur the famous Falls of Niagara, where the river, 1075 yards wide, falls over a precipice from 150 to 160 feet in height. The newly-discovered lakes in Central Africa probably rank next in size,—the *Victoria* and *Albert Nyanzas* and *Lake Tanganyika*. Their area is not known; but the Victoria lake is estimated at 200 miles from north to south, and 300 from east to west; the Albert lake is estimated at 350 miles from north to south, and 500 miles in the opposite direction; their heights above the sea are 3720 feet and 2720 feet respectively. The Lake of *Titiçaca*, in the Bolivian table-land, is the highest lake known; it is 12,846 feet above the Pacific.

Distribution.—A peculiarity in the distribution of the great lakes is their tendency to occur in groups. Thus, in North America, where the most important series exists, we have, commencing in the North-west, the Great Bear and the Great Slave Lakes, Lake Athabasca, Lake Wollaston, Deer Lake, Lakes Winipeg, Winipegoos, and Manitoba; then come Lakes Superior, Michigan, Huron, Erie, and Ontario; the whole forming the most magnificent series of lakes in the world. No other lakes at all comparable with these in size occur throughout the rest of America, North or South. In Europe, the chief lakes again occur as a group in Finland and Russia, where lakes Ladoga,[1] Onega,[2] Saima, Peipous, Ilmen etc., occur within a circumscribed area. The Caspian and Aral are different from any other of the lakes we have been noticing, as has been explained; but even here a tendency to grouping is observable; and if at some future period, as may be the case, the Black Sea should be separated from the Mediterranean, as the Caspian has been, this tendency would be much more striking. The two remaining districts, in which large lakes occur are Central Africa and Central Australia, and here again they are found grouped together.

The only notable exceptions to this rule are found in Central Asia, where Lake Baikal to the east, and Lake Balkash to the west, are cases of large lakes unconnected with any group. The lake of Titiçaca is solitary; and Lake Tchad, in Africa, is perhaps another instance. Besides these, there are no other large sheets of inland water.

Small lakes are particularly abundant in mountain regions, and are often remarkable for the lovely scenery in which they are embosomed. Our own lakes in Scotland, the north of England, and the south of Ireland, vie in beauty with the grander examples among the Alps. Nearly every mountainous district abounds in lakes, but they are never of any great dimensions. A striking exception to this occurs in the case of the Himalaya Mountains, for they contain scarcely any lakes whatever. *Lake Waler*, in Cashmere, is the largest, and it is only about the size of Loch Lomond.

The largest lake in England is *Windermere*, with an area of 10 miles; in Scotland, *Loch Lomond* (43 square miles); and in Ireland, *Lough Neagh* (156 square miles), which is, however, not a mountain lake. Of the Swiss lakes, the *Lake of Geneva*, or *Lac Leman*, takes the lead, with an area of 240 square miles.

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[1] Area 6633 square miles. [2] Area 3280 square miles.

CHAPTER V.

VAPOUR.

A. EVAPORATION.

Evaporation is that action of the sun's heat by which water is raised into the atmosphere in the form of invisible vapour. At all temperatures water loses some of its substance in this way, even ice obeying the same law. The amount thus raised depends upon—

1. *The intensity of the heat:* the greater the heat, the greater the evaporation.

2. *The amount of vapour already in the atmosphere:* a given quantity of air, at a given temperature, can only take up a certain amount of moisture.

Water being heavier than air, it would seem difficult to explain why they mix so intimately; but this is only one of many such curious facts in nature. Air itself is a mixture of two gases, one heavier than the other, and yet they never separate; indeed, they would mix again if separated, the lighter gas descending to mix with the heavier, and the heavier rising up to mix with the lighter. Why this is we cannot yet tell; but we know it to be a fact, that if two gases be brought together, the lighter of the two, instead of floating upon the heavier, will mix with it. Now water in a state of vapour acts just like a gas, mixing with the lighter air without falling, in very much the same way as sugar will dissolve in water without settling to the bottom.

But as the water will not hold more than a certain amount of sugar dissolved or mixed with it, so air will not hold above a certain quantity of water mixed with it. When as much sugar has been added to the water as it will hold, it is said to be *saturated;* and when the air contains as much moisture as it will hold, it is also said to be *saturated.* If now we add any more sugar, it will fall to the bottom; and if any more vapour be added to the air, it will descend as rain. But if we heat the water we shall find it will take more sugar; and the same holds good for air. However, there is a limit to this; for though the water be heated until it boils, it can only dissolve a certain quantity of sugar; and so it is with air, though this point is never reached, for the air is never made hot enough. We now see the reason for the two laws laid down at the commencement of this article, namely, that the *amount* of evaporation depends upon the intensity of the heat, and upon the quantity of vapour already absorbed by the air.

B. CONDENSATION.[1]

1. **Dew.**—Dew is one form under which vapour is returned to the earth as water. Its mode of formation is as follows. During the day the earth has been continually receiving warmth from the sun, but when the evening comes on, and the sun has set, the earth begins to give off some of this heat, or to *radiate* it, as it is called. All bodies, however, do not radiate equally: some, as grass, wood, glass, etc., being good radiators; and others, as metal,

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[1] L., *con*, more, and *denso*, to make dense. Condensation is the opposite of evaporation. In this case the invisible vapour is brought back to its watery state.

gravel, and rock, being bad radiators. These good radiators part with their heat rapidly, and the air in contact with them becoming cooled, cannot hold so much vapour as before, and hence deposits it, forming dew. The temperature at which dew begins to be deposited is called the *dew-point*, and it varies with the amount of moisture contained in the air, for if the air be already very nearly saturated, a much slighter lowering of temperature will bring it to the dew-point than if it held but little moisture.

Dew is often seen heavily deposited upon the grass and plants in a garden, while the gravel walks remain dry. This is because the latter is a bad radiator, or in other words, does not part with its heat so readily as the plants.

For the deposition of dew several conditions are necessary: these are (1) *an unclouded sky*, otherwise the heat cannot be radiated, but is thrown back again; (2) *a calm night*, for if a wind blow, it prevents the cold air remaining in contact with the radiating body by removing it as soon as formed; (3) *a warm dry day preceding*, to charge the atmosphere with vapour, and (4) the exposure of good radiators. In proportion as these conditions are more or less perfectly found, so is the dew more or less perfectly deposited. In tropical countries these conditions generally occur in perfection, and consequently the dew is very copiously deposited.

The chilling effect of radiation extends only a very small distance above the ground. A *thermometer*[1] exposed on long grass will show a temperature 18° F. below another placed a few feet above the grass. Even at two or three inches above the grass the chilling is only one-half. Generally the radiating body is about 4° below the temperature of the air immediately above it; but this tends still further to lower the temperature of the air. The radiating body again falls below the temperature of the air, and this decrease may continue until a temperature below freezing-point is reached, when the dew becoming frozen is deposited as *hoar-frost,*[1] or *white frost.*

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[1] Gr., *therme*, heat, and *metron*, a measure. An instrument for measuring heat.

The slightest covering, a light matting or even a cobweb, is sufficient to protect plants from the chilling and destructive effects of dew and hoar-frost, by preventing radiation, and therefore retaining a temperature around the plant equal to that of the air above.

In some countries moisture is deposited in a state intermediate between dew and rain. It is called by the French *serein*, and has no English name. It is produced on fine unclouded nights, shortly after sunset, and falls as an extremely fine rain.

2. **Fog and Mist.**—When the vapour in the air is rendered visible near the surface of the earth, or clinging to mountain sides, it is called *fog* or *mist.* Fogs are produced by currents of air laden with moisture coming in contact with the colder surface of the earth, by which the vapour they contain is partially *condensed*, and becomes visible as fog or mist. Some places are much more favourable to the production of mists than others; such as mountain sides, which obstruct the passage of the winds and condense their vapour; and valleys, especially those along which streams flow. But generally speaking cold countries are foggier than warm; the banks of Newfoundland are especially subject to dense fogs, owing to the condensation of the moisture taken up from the heated waters of the Gulf Stream. Sea-coasts are more subject to fogs than inland places.

Dry Fogs.—This peculiar phenomenon may be noticed here, though it is not produced by the vapour suspended in the air; indeed it receives its name from this fact, as the most delicate instruments have failed to detect any moisture in it. Dry fogs are of rare occurrence. One happened in 1783, which extended from Africa to Sweden, and covered great parts of North America. It commenced on the 18th of June at widely different places, as Paris, Turin, Avignon, and Padua, and lasted a month. It was found at all accessible heights above the surface, was not affected by the wind, nor dissipated by rain, and seemed to be slightly luminous, there being no absolute darkness while it lasted. In 1831 another such fog of equal extent occurred, spreading over Europe, Asia, North Africa, and the United States; commencing on the north coast of Africa on the 3rd of August, reaching Russia on the 9th, France on the 10th, the United States on the 15th, and China by the end of the month. It was so dense that the sun could be viewed through it without the aid of smoked glass. Like the other fog it lasted a month.

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[1] *Hoar*, originally hairy, especially gray or white hair

No explanation of these fogs has been yet given that is at all satisfactory. The supposition that they are the result of the earth passing through the tail of a comet is out of the question, because no comet was visible about that time, and the fog, though widespread, was not continuous, wide spaces being entirely free from its presence. Another idea is that the fog might be the vapour and smoke from volcanic eruptions, as violent eruptions took place in the Mediterranean region in 1783. This is plainly incompetent to explain the phenomena, not indeed from the immense distances the matter would have to be carried,[1] but from the fact that these fogs happen, as in 1831, when there is no great volcanic activity. A third conjecture is that they owe their origin to the same cause as that which brings about showers of meteoric stones; nothing is known either for or against this idea. So it is neither proved nor disproved as yet, neither has any competent cause been offered in its place.

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[1] The smoke from the forest fires of the United States this year (1871) was carried over a thousand miles out into the *Atlantic.*

3. **Clouds.**—When vapour is condensed so as to become visible at considerable elevations, the masses so formed are called *clouds*. Clouds therefore owe their origin to precisely the same conditions as fogs, the only difference being that in the one case the vapour is condensed near to the earth, and in the other at some distance above it.

So long as the vapour floats as an invisible gas in the air, its suspension was easily accounted for; but when it resumes the watery state, as in fogs and clouds, and still remains suspended, it is by no means so easily explained. Indeed we know of no reason why vapour when condensed should not be at once precipitated as rain, instead of passing through an intermediate state of fog or cloud.

(*a*) *Movements.*—The rate at which clouds move is often much greater than the speed at which the wind is travelling close to the ground; the apparent slowness of their motion is owing to their height above the observer. From 70 to 100 miles an hour is not an unusual speed. Some clouds, however, are quite stationary when the wind is blowing with great force, especially in mountain regions. Mount Pilate in Switzerland, Table Mountain in South Africa and the Matterhorn very often afford illustrations of this kind of cloud. They are caused by the condensation of the vapour on meeting with the cold mountain side, and as the chilling influence extends some little distance from the mountain, the cloud does not cling to it, but *forms before* reaching, and continues beyond it.

Although the cloud is stationary, *the material composing it is not*, but is constantly changing, as might soon be proved on ascending the mountain, when the cloud would be found to consist of a driving mist. The moisture in the air is simply rendered visible on passing that spot.

The daily movements of clouds will be noticed when the different classes are described.

(*b*) *Height.*—The cloud region in England varies from 2000 to 6500 feet above the ground, and is from 2000 to 3000 feet thick, with the same temperature at the top as at the bottom. Certain clouds (*cirrus*), however, are much higher in all countries, and even appear still to be at great heights when viewed from a balloon 23,000 feet above the earth. In the trade-wind area the cloud-region is somewhat higher, ranging from 3000 to 5000 feet in altitude. As a rule the cloud-region is higher over land than over sea, and the further inland we go the higher the clouds are; but in the case of the trade-wind region this is reversed, and the clouds are higher over the sea than over the land. Professor Smyth while living on Teneriffe continually noticed a cloud-bank, drifting with a north-east wind at an elevation of 4500 feet, and another moving south-west, that is, directly opposite, at the height of 15,000 feet.

(*c*) *Classification.*—Clouds are grouped into three original forms, and four arising from combinations of the others. The names are as follows :—

Original.

1. **Cirrus**,[1] or curl cloud.
2. **Cumulus**,[2] or summer cloud.
3. **Stratus**,[3] or fall cloud.

Combined.

4. **Cirro-stratus.**
5. **Cumulo-stratus.**
6. **Cirro-cumulus.**
7. **Nimbus**, or rain cloud.

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[1] L., *cirrus*, a curl.

[2] L., *cumulus*, a heap.

[3] L., *stratus*, a layer.

1. *Cirrus.*—These clouds are so called from the beautiful curl their fragments often assume. Mackerel skies, mare's tails, and cat's tails, are some of the forms these light fleecy clouds present. They have a remarkable tendency to form into parallel bands, each belt being composed of light airy fragments. These bands at the equator extend from north to south; in higher latitudes, as in England, they stretch from north-east to south-west, varying however from that to north-west and south-east. They are the highest of all clouds, being seldom less than three miles (15,840 feet) high, and often five or six miles (26,000 to 30,000 feet). They are believed to consist of vapour below the freezing-point, that is, they are composed of minute particles of ice and snow. Among these clouds the mock suns, which form so striking a feature in Arctic voyages, are formed.

2. *Cumulus*, or summer clouds, are those rounded forms which are often grouped together in fantastic shapes; a very common appearance being that of a range of snow-crowned mountains glistening in the sun. Sometimes they appear as dense masses covering the whole sky. They are formed soon after sunrise, and ascend higher as the day advances, melting away towards evening, when the ascending currents to which they owe their origin give place to descending currents.

3. *Stratus* or *fall-cloud*, is the name given to the bank of clouds which spreads along the horizon towards sunset (the *fall* of the day), and vanishes at sunrise. The mists which creep over the meadows and along the valleys, belong to this class of cloud. It is formed by the vapours which rise from the earth as it cools by night, and is dissipated by the warm rays of the succeeding day.

The remaining clouds are as their name signifies, *merely combinations* of the above, partaking of the character of two of them. The seventh class, the *Nimbus*, or rain-cloud, is distinguished by its leaden grey colour, and, often when discharging rain, by the ragged appearance of its lower portion, which seems to be frayed out. This class of cloud is formed from any of the others, except the cirrus, especially from the cumulo-stratus, and is always low down, ranging from 1000 to 5000 feet.

4. **Rain.** (*a*) *Formation.*—When currents of air laden with moisture are so cooled that they cannot hold all they contain, a portion is discharged as rain. If the air holds the water as invisible vapour, and is then cooled, a cloud is first formed and afterwards the rain is deposited. Sometimes clouds form and discharge very rapidly; sometimes the process is very protracted. The cooling of the moist currents of air may take place in the atmosphere, or by contact with the sides of mountains. In the latter case it may happen that the mountains are so high that every trace of moisture is wrung from the wind before it reaches the summit, in which case it passes over to the opposite side of the chain as a dry wind. In this manner the rainless districts of South America arise; the warm, moist winds from the Pacific discharging their vapour in copious rains on the western slope of the Andes, leaving their last tribute as a snow capping to the mountains, and then passing on to the desert regions in question.

The opposite to this takes place when a moist wind traverses a dry, hot region; as when the winds blowing across the Mediterranean reach the coast of Africa. The air becomes heated, and its capacity for holding vapour increased, so that the clouds, apparently ready to discharge as rain, become dissipated into vapour; instead of which, the desert sky is always bright and clear, even when the coast and sea are overcast with cloud.

(*b*) *Amount of Rainfall*—The rainfall at any place is estimated in inches; thus, when it is said that the mean annual rainfall in England is 30 inches, it means that the amount of rain falling in England in a year is sufficient to cover it to a depth of 30 inches.

Speaking generally, the greatest rainfall is in the tropics, and it decreases as we recede from the equator. In the tropics the average rainfall is about 96 inches per annum; in the temperate zones, 35 inches; and in high latitudes, much less; in latitude 60° it is only 16 inches. The average for the whole earth is about 60 inches. These results are not to be taken as more than mere approximations; for the rainfall is so dependent upon local circumstances, that vast areas occur within the tropics where no rain ever falls, and some places in temperate regions have an almost tropical rainfall.

The greatest actual rainfall is in Guiana, Brazil, and north and western India, where the average is over 300 inches. At Cayenne, in Guiana, 21 inches have been known to fall in 24 hours, and at Chirrapoonjee, in Bengal, 30 inches fell in the same space of time.. Dr. Hooker records a fall of 530 inches between June and November, 1850, the most excessive rainfall ever witnessed. These exceptionally large deposits are not confined to hot countries; for instance, at Seathwaite in Cumberland, 182½ inches fell in the year 1862, and only 20 at Bishopswearmouth in Durham. The explanation of these cases, in all instances, is, that warm moist winds are intercepted[1] in their passage by mountain chains, and forced to ascend their sides, and, becoming cooled, discharge their moisture as rain.

(c) *Conditions.*—The most favourable condition for the production of a large rainfall, is exposure on a coast to warm moist winds blowing from the sea; if the coast be high, the rainfall is increased. The west coast of Great Britain is exposed to the Atlantic Ocean, while the east coast has the continent of Europe opposite to it. The south-west is, therefore, the rain-wind, and the north-east the dry wind; accordingly we find that the average rainfall on the west coast is 45 inches, and on the east coast only 27 inches. The influence of elevation is seen in the cases of Liverpool and the Lancashire moors; the former, lying low, has a rainfall of 22 inches, while 45 inches fall upon the high ground of the latter. Again, the mountain region of Europe has an average fall of 42 inches, and the plains only of 23 inches.

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[1] L., *inter*, between, and *ceptum*, taken. To take away by coming in between, to cut off.

The unfavourable conditions are, remoteness from the coast; exposure to winds coming from a colder region; situation under the lee of high land which intercepts the rain-winds; and, in hot countries, the absence of vegetation. When these conditions are perfectly fulfilled, rainless districts are the consequence.

(*d*) *Distribution of Rain through the Year.*—The rainfall at any place is not distributed equally through the year; in some cases it is crowded into a short space of time, during which rain falls very heavily; in others, it is more evenly spread over the year. In the tropics, where the rainfall is greatest, the number of rainy days is least; and as the amount of rain decreases, the number of rainy days increases. The number of rainy days in temperate climates depends largely upon the conditions mentioned in the last paragraph. The influence of the S.W. rain-wind of the Old World is seen by the fact that on the west coast of Ireland it rains on 208 days in the year; in England, the average is 152 days; in central Germany, 141 days; and in Siberia, far away from the coast, 60 days is the average number.

The tropics are the regions of periodical rains. In those districts the year is divided into rainy and dry seasons, which are determined by the latitude of the place and the position of the sun. As the sun moves north of the equator, the rain follows it; and hence the rainy seasons in the northern tropic region are between March and September. Between the parallels of 5° and 10° N. and S. latitude there are two rainy seasons, one each time the sun passes over on its journey to either tropic. South of the equator, the rainy seasons are in the latter and early portions of the year, the sun being at those times overhead in that particular region.

In the Indian Ocean it is not the position of the sun that directly influences the rainy season, but the monsoon which happens to be blowing on to the coast. Hindostan affords a good example of this dependence of the rainy season upon the monsoon. While the S.W. monsoon is blowing (from April to October), the western coast is watered, and the eastern coast has its dry season. When the N.E. monsoon prevails (October to April), the east coast has its rainy season, while the west coast enjoys fair weather.

The regions beyond the tropics, are the districts of variable rains. In these localities the rain is not confined to any particular season, but falls indiscriminately throughout the year. The showers are much gentler than in the tropics, and they fall as often by night as by day, whereas the periodical rains usually fall between the hours of noon and five o'clock in the afternoon.

The rain is not equally distributed through the various months, but is more prevalent in some than in others, hence the north temperate zone has been divided into regions of *summer*, *autumn*, and *winter* rains.

(1) *Summer Rains.*—The district over which the chief rains fall in the summer months includes all Central Europe. the Carpathians, Germany north and

east of the Alps, North Switzerland, the Netherlands (except the Rhine delta), Denmark, and Southern Scandinavia.

Autumn Rains.—The district of autumnal rains embraces north-western Scandinavia, the British Isles, the Rhine delta, nearly all France, northern Spain and Portugal, the north of Italy, Turkey, etc.

Winter Rains.—This district covers northern Africa, Southern Spain, and Portugal, the south of Italy, Greece, and north-western Asia.

In extra-tropical South America, winter is the season when the greatest rain-fall occurs; but in Tierra del Fuego, it is said to rain and snow almost continually. South Africa and Australia also have their rainiest seasons in the winter months.

Summary. Notwithstanding the extreme variability of the rainfall, the earth may be divided into three rain-provinces. One zone of periodical rain, included within the tropics; and two zones of variable rain, one lying to the north, the other to the south of the tropical zone. In the zone of periodical rain there is a narrow belt lying between 4° and 9° N. latitude, upon which rain falls nearly every day. This is called the *zone of constant precipitation*, and it is coincident with the equatorial belt of calms, to be described in the article on Winds.

5. **Rainless Districts.**—The greatest extent of rainless country is the immense desert region which runs almost uninterruptedly from north-west Africa into the centre of Asia. It is naturally divided into two districts, one west of Hindoo Koosh, and including the deserts of Persia, Syria, Arabia, and Africa, and the other lying east of those mountains, and known as the desert of Sha-mo, or Gobi. We will call the former the Western rainless district of the Old World, and the latter, the Eastern rainless district.

(A.) OLD WORLD. *Western Rainless District.*—

This district has an area of about 3,000,000 square miles. It is for the most part a waste of sand, lying perfectly even at a slight elevation above the sea, being lower on the west than on the east.

While the sun is north of the equator, this region lies within the sweep of the N.E. trades, which, having travelled entirely over land (the Mediterranean excepted), are dry and parched before reaching this district. When the sun goes south, the region comes more within the sweep of the anti-trades, which have long since deposited their moisture upon the western coast of Africa.

Eastern Rainless District.—The area of this district is about 2,000,000 square miles, and it owes its aridity to the same causes as the western district, namely, its situation within the sweep of the trades, and to the cutting off of the supply of moisture from the south by the intervention of the Himalaya mountains.

(B) NEW WORLD. The rainless districts of America amount in all to less than a million square miles. They owe their character in every case to their situation under the lee of mountain chains, which intercept the rain-winds.

The region of California and Utah is cut off from its supply of rain by the Rocky Mountains, which receive the anti-trades on their western slopes, and drain them of the moisture they contain, after which they flow onwards as dry winds.

The Mexican Plateau, the west coast of Guatemala, and the coasts of Peru and Bolivia, lie within the region of the N.E. trades, which deposit their rain on the eastern slope of the mountains, and are hence dry when they arrive at the above districts.

Patagonia is nearly rainless, as it lies under the lee of the Andes, which intercept the anti-trades, the rain-winds of that area.

6. **SNOW.** *(a) Cold Region of the Atmosphere.*—Above

a certain altitude, water can at no time exist unfrozen. In the summer months this elevation is much greater than in the winter; but it is at no period so far above the level of the sea that the peaks of high mountains do not reach it. There is, in fact, perpetually hovering over our heads, a region wherein the climate is as rigorous, the cold as intense, as is found amid the polar snows. In summer it is lifted so as not to touch the surface at all in our hemisphere; but we are reminded how near it is to us by the snow-capped mountains and the cirrus clouds floating in the air. In winter it settles upon a large portion of the northern hemisphere, and is raised from the southern hemisphere, upon which it rested during our summer. If we take a common terrestrial globe of the large size used in schools, and put a case over it to represent this cold region hanging over us, it would fit so closely as to seem to touch in every part; and if we were to cut the globe and its case in two, no space could be seen between them. At its greatest altitude, under the equator, it is not four miles above the sea. Its summer height is known as the *snow-line*, because, when mountains reach it, they are capped with snow. The sun's heat alone maintains this cold region suspended; and when that heat is diminished, as in winter, we find it approaches nearer to us. Geologists assure us that the time has been when it settled so close to the earth that intense cold prevailed everywhere.

The elevation of the cold region differs in the same latitudes, owing to local circumstances. As we judge mostly of its altitude by the snow-line, this fact is usually expressed by saying that the snow-line varies; but as the cold is there, whether there be mountains or not to pierce it, a more correct expression is, that the cold region varies in height in the same latitudes. Mountains are a cause of this variation, and so are all circumstances which tend to modify the climate; for the raising of the temperature is equivalent to pushing the cold region further from the earth.

Snow-line.—The elevation of the cold region at the warmest part of the year, is the point at which the sun's rays cease to be powerful enough to melt snow. When mountains are sufficiently high to reach that point, the moisture is deposited upon their summits as snow, and would continually increase in thickness if it were not relieved by glaciers. In the tropics the mean elevation of the snow-line is about 15,000 feet. At Quito, on the equator, the snow-line is at 15,795 feet; to the north it diminishes, being at 14,772 feet, in latitude 18°. Southwards the snow-line rises for a time in Peru and Bolivia, reaching the elevation of 17,000 and 18,000 feet; it then again sinks, being found at 13,000 feet in North Chili, 12,780 feet at Valparaiso, in Central Chili, 8000 feet in South Chili, and so decreasing to 3390 feet in the extreme south of the continent of South America.

The effect of the desert region of Asia is seen in the remarkable phenomenon of the snow-line being higher on the north than on the south side of the Himalaya Mountains. On the north side the snow-line averages about 17,000 feet, on the south side only about 13,000.

On Kilmanjaro, in Africa, the snow-line is at 17,000 feet, on Etna at 10,000, on the Pyrenees at 9000, on Mont Blanc at 8500, in Central Norway at 4000, and on the Arctic Circle at 2000 feet.

On the North American Continent the snow-line decreases in altitude much more rapidly; and in the Southern Ocean snow remains unmelted through the year at the sea-level in latitudes corresponding to Yorkshire.

(*b*) *Limits of the Fall of Snow.*—Snow never falls at the sea-level within the tropics. It has been known to fall at Canton, on the tropic of Cancer; but this is a *very exceptional* occurrence.

In the western portion of the old world snow is rare below the 45th parallel; but it does fall as far south as latitude 30°, there being probably no place in Europe where snow is not seen sometimes.

In the eastern portion of North America, snow has about the same limit as in Europe, but on the west coast it does not fall below latitude 48°.

In the southern hemisphere snow rarely falls below latitude 48°, but it is an occasional visitant in Cape Colony (lat. 32°), and at Sydney (lat. 38°). (*Herschel.*)

(*c*) *Nature of Snow.*—A snow-flake is not a congealed drop of rain; but a beautifully crystallized particle of water. When the temperature falls considerably below freezing point, during a snow-storm, the crystals can be very easily seen. They usually take the form of stars, always having six sides or rays, which branch off at an angle of 60°. Over a hundred different forms have been noticed, and there are probably many more; but in all their beautiful and fantastic variations the same six-sidedness is observed, and the same angle of 60°.

Snow is a bad conductor of heat; and it acts upon the ground and vegetation upon which it rests in the same way as the "cosy" acts upon the tea-pot, preventing loss of heat by radiation. It is, therefore, a valuable protection to vegetation during the severity of winter, saving many plants from certain death by freezing.

7. **Hail.** (*a*) *Formation.*—Hail is believed to be formed in the higher regions of the atmosphere; but its origin is not clearly established. It is in some way connected with a change in the electrical condition of the atmosphere, for thunderstorms very frequently happen while hail is falling.

(*b*) *Nature.*—Hail-stones are formed of opaque, frozen water; they are sometimes coated with transparent ice, and occasionally consist of layers of snow and ice. Their usual form is pear-shaped; but Prof. Ramsay has seen them assume the form of six-sided prisms. Their size is usually small; but occasionally they are as large as hens' eggs, and masses have been known to fall measuring a yard in diameter, formed by the freezing together in the atmosphere of a number of large hail-stones.

(c) *Hail-storms and their Distribution.*—Hail-storms are most common in the summer season, and in the day time. They are usually very limited in their extent, but are destructive in the extreme to crops; so much so, that a Hail-storm Insurance Company exists, for the purpose of insuring farmers against the damage. Much damage is done to buildings during severe hail-storms; and animals, such as deer, sometimes fall victims to their fury. These storms occur in nearly all latitudes, but are most frequent in situations near to mountains. They are rare on the low plains in the tropics, but common at an elevation of a few thousand feet.

8. **Ice.** (a) *Formation.*—Take a vessel containing water; mark the height at which it stands, and then heat the water, and it will expand. If, now, we allow it to cool, it will decrease in volume until the temperature has fallen to its original point, when the water will occupy the same space once more. Suppose the water to be still further chilled, it will continue to shrink in volume until the temperature of 39° F. is attained, when the shrinkage stops. At this temperature water is denser, and therefore heavier, than at any other. If the temperature falls below 39° F. the water again expands, and continues to do so down to 32° F., when it freezes, and, becoming solid, is called *ice*.

The expansion above described is of very great importance, since without it ice, which now floats upon the surface, would sink, and rivers and lakes would become converted into solid masses of ice, destroying all living things, both animals and plants, which find their homes in the waters. As it is, ice is only nine-tenths the weight of water, or in other words, floating ice has one-tenth of its bulk above water.

(*b*) *Structure of Ice.*—The act of freezing is a process of crystallisation, and if a piece of clear ice be taken, and a ray of light be passed through it, the crystals, by the partial melting of the ice, become visible as six-rayed stars, the same character as we found in snow. Pure ice found in calm weather on the still surface of a lake is almost free from air, and all ice consists of pure water, no matter what foreign substances may be dissolved in it. The ice of frozen seas contains no salt, except a little accidentally entangled in its pores.

GLACIERS.—The valleys of many of our snow-capped mountains are filled with huge masses of ice, called *glaciers*,[1] which creep down below the snow-line into warmer regions, and terminate as a wall of ice which rapidly melts and gives rise to a stream.

(*a*) *Origin.*—Glaciers have their origin in the snows of mountains. If this snow were not in some way removed, it would go on increasing year after year to an enormous thickness, and would add appreciably to the height of the mountain. This does not take place, for the snow is constantly being removed, partly by evaporation, chiefly by glaciers. The lowest portions of the snow upon the mountains have to sustain great pressure from the overlying mass; where it is deepest the pressure will be greatest. In the valleys the snow gets pressed into a compact mass, which is called *névé*,[2] from which névé the glacier is formed by further pressure. A glacier is a river of ice; and if we follow it to its termination, we find it converted into a river of water. The Rhone, for example, rises from a glacier.

(*b*) *Structure of Glacier-ice.*—The ice of glaciers is not like that formed on rivers and lakes, but is striped; being made up of alternate layers of clear blue ice, and less compact white ice. This peculiar *veined structure*, as it is called, is the result of ice being formed from snow under great pressure, just as the similar flakiness of puff-paste is caused by continued rolling. The veining is always at right angles to the direction of the pressure.

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[1] Fr., *glacier*. [2] Fr., *névé*.

(*c*) *Description of a Glacier.*—The surface of a glacier presents every variety of appearance, from comparative smoothness, to extreme ruggedness, when the ice is broken up into fantastic pinnacles. In many places gaping fissures called *crevasses*[1] abound, down which streams, formed by the melting of the surface, are precipitated. The sides of the glacier are lined with an accumulation of stones which have fallen on to its surface, and are carried onwards to be finally deposited where the glacier ends, far away from the point from which they were broken. These lines of stones are called *lateral*[2] *moraines;*[3] the heaps deposited at the ends of the glaciers, *terminal* moraines. When two glaciers join, the *inside* moraines of each unite, and being carried onward by the movement of the glacier, form a *medial*[4] *moraine* in the centre of the glacier. It is partly from the presence of moraines in districts, such as England, where no glaciers exist, that their former presence is inferred.

The glacier moves onward until the melting of the ice equals the rate of movement, and the end of the glacier "may be compared to an endless file of soldiers, pouring into a breach, and shot down as fast as they advance." The bed of the glacier is usually tunnelled by the water which falls through the crevasses; and at the termination, a stream laden with mud and stones issues from a cave of ice.

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[1] Fr., *crevasse.* [2] L., *lateralis*, the side. [3] Fr., *moraine.* [4] *L., medialis*, the middle.

(*d*) *Nature of Motion.*—Careful observation has shown that the motions of glaciers and rivers are precisely the same. The sides of the glacier, retarded by rubbing against the banks, move slower than the centre, and the surface moves faster than the bottom. The line of fastest motion occupies the centre where the glacier is straight, and draws off to the outside of the curve where the course is *sinuous.*[1] In all these respects it exactly resembles the flow of water in a river. The rate of movement is greater in summer than in winter, and the yearly motion varies in different glaciers from 14 feet to 700 feet.

(*e*) *Cause of Motion.*—Ice being a solid, it is difficult to see how a glacier can move in the manner just described; and this difficulty is increased when we consider that the valleys through which glaciers flow, are of varying width and irregular course. It is plain, that if the glacier were a rigid mass of ice, its various portions could not move at different rates, nor could it adapt itself to the changing size and shape of its valley, any more than a rigid bar of iron could, by pushing, be made to move quicker in one part than another, or be driven through a winding groove contracted in places to less than the width of the bar.

If ice were plastic, like tar or treacle, all these difficulties would vanish; but it is not. It, however, possesses a peculiar property, called *regelation,*[2] which enables it to act much as if it were plastic. If two pieces of ice be brought into contact, they immediately freeze together. A shapeless lump of ice placed in a mould, and broken into small fragments, will freeze into a solid piece of ice the shape of the mould, if pressure be applied to make the fragments touch. It is regelation which effects these changes. In consequence of this property, the glacier can be squeezed through narrow gorges and circuitous valleys, for the ice becomes broken, and again freezes, and so works its way along.

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[1] L., *sinus,* a bend. [2] L., *re,* again; and *gelo,* to freeze.

(*f*) *Effects of Glaciers.*—Glaciers relieve the mountains of their excessive snows; but besides this, they operate very powerfully upon the rocks over which they pass, grinding them into dome-shaped masses, which are called *roches moutonnées*,[1] from a fancied resemblance to sheep's backs. All the surfaces over which a glacier passes are scratched and polished by th pebbles frozen into the bottom and side of the ice and often blocks of stone are perched in strang places where the ice has shrunk below a former level There is evidence of all glaciers having been muc larger than at present, and large tracts of countr show evidence of their former presence in th rounded forms and scratched surfaces of the rocks An ordinary photograph will show, that the highes portions of mountain ranges are peaked, while th lower parts are moulded into tamer forms by ice action. Great Britain, and many other countrie offer unmistakable evidence of glacial action.

(*g*) *Size.*—Glaciers, like streams, are of all sizes The great glaciers of the Alps are between te and twenty miles in length, and with an averag breadth of a mile. The Himalayas, Greenland and other parts of the world possess much large glaciers.

ICEBERGS.—In high latitudes glaciers descend t the sea, and immense masses breaking off, float awa and form icebergs. They vary in size from smal blocks to huge masses, several miles in circumferenc and two or three hundred feet above the water: thi height must be multiplied by nine to give an idea o the thickness of the whole, since for every par projecting above the surface, from eight to ten part are submerged. Large icebergs have been seen aground in 1500 feet of water in Baffin's Bay.

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[1] *Fr.*, *roche*, a rock; *moutonné*, sheep-like.

(*a*) *Limits to which Icebergs extend.*—The limits of icebergs are of course determined by the size, for the larger they are, the longer they take to melt; and the further they are carried by currents into the warm regions. In the Atlantic, the icebergs are carried by the polar current down the western coast, and occasionally reach as far south as the latitude of the Azores (40°): from the south, icebergs travel northwards, very near to the Cape of Good Hope (30°).

(*b*) *Effects of Icebergs.*—Large icebergs sometimes strand on the coasts of Newfoundland and Iceland, and remain for years. During this time so cold does the climate become, that the crops fail. Bad weather, rain, and clouds accompany them, and they are often shrouded in mist. Like glaciers they are laden with stones, which are strewn over the bottom of the sea as they melt, giving rise to thick beds, such as we now find over parts of our own country.

GROUND ICE. — Singularly enough, under some circumstances, ice forms at the bottom of rivers and ponds. This has been noticed in the Thames, and in the rivers of Siberia, and we have seen the same thing in the rivers of the Fenland. This ice is called *ground-ice.* It is formed more readily under clear than under cloudy skies, and on rocky and pebbly than on muddy beds. Its origin is obscure, but we may perhaps liken it to a subaqueous[1] hoar-frost, caused by radiation from the surface of the bottom.

SEA ICE.—The sea freezes at a temperature of $28\frac{1}{2}$° F., or $4\frac{1}{2}$° lower than fresh water. The ice is fresh, but contains a little salt caught up in the process of freezing. The frozen surface forms what is called

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[1] *L.*, *sub*, under; and *aqua*, water.

field-ice, and when the warm weather causes the field to break up, the fragments crash together with terrific force, and become piled up to immense heights: it is then called *pack-ice*. Drifting ice-fields are called *floes*.

Limits of Ice-Fields.—The polar seas are entirely closed during great portion of the year, being open for a few months only in summer. The ice has its usual southern limits, in the North Atlantic, to the north of Iceland, bending somewhat southward towards the American coast. In the south there is a permanent ice-pack extending from the 65th to the 70th parallel of latitude, which at all seasons bars the further progress of vessels.

CHAPTER VI.

VOLCANIC ACTION.

Definition and Divisions of the Subject.—"Volcanic action," says Sir C. Lyell, "may be defined to be the influence exerted by the heated interior of the earth on its external covering." In considering this subject we shall examine

1. The proofs of the existence of a heated interior.
2. The phenomena of volcanoes.
3. Earthquake movements.
4. The rising and sinking of land in countries where there are no volcanoes.[1]

1. **Proofs of a Heated Interior.**—In a former chapter we have remarked that the shape of the earth is precisely such as it would acquire if it had cooled from a molten mass revolving upon its axis (p. 6).

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[1] *Vulcanus*, belonging to Vulcan, the god of fire.

We shall here consider whether there yet remains any of this central heat capable of raising the temperature of the globe above what it would acquire from the sun's heat alone. The presence of hot springs and volcanoes over such wide-spread areas would in itself afford strong grounds for believing in the existence of subterranean[1] heat, and experiment has shown that as we descend into the earth's crust, the temperature in all cases rises. In very deep *Artesian*[2] wells, the temperature of the water is always found to be higher than water at the surface; thus in the celebrated Artesian well at *Grenelle*, near Paris, sunk in 1834, water rose from a depth of over 1800 feet, having a temperature of 82° F. Now, as the average temperature of springs in that district is about 52° F., this gives us an increase of 30° F. at a depth of 1800 feet, or 1° F. for every 60 feet in depth. Many other instances may be cited, but as the result is in all cases similar, examples need not be multiplied.

The fullest examination into the internal temperature of the earth has been made in mines, and the results are briefly as follow. The influence of summer and winter temperature is felt to a depth of about 100 feet. Within this *zone of variable temperature*, as it is called, the cold of winter and the heat of summer exercise a distinct influence. Beneath this occurs a *line of invariable temperature*, in which the same temperature is found to continue throughout the year.[3] This temperature though constant for any given place, is not the same everywhere. Descending below this line, we come to the region in which a gradual increase of temperature is observed as the depth increases. In making observations on the rate of increase, the following sources of error must be avoided; (1) the influence of currents of air of different temperatures in the mine; (2) the friction of working; (3) the heat derived from the men and candles; and (4) from the gunpowder used in blasting. All these tend to elevate the temperature, but after they have been allowed for, there still results a most marked increment[1] of temperature, affording not the slightest grounds for doubting the existence of internal heat. The facts brought to light by these experiments, may be thus summed up.

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[1] L., *sub*, under, and *terra*, the earth: under ground. [2] From *Artois*, in France, where they were used many years ago. [3] In the vaults of the Paris Observatory, 88 feet below the surface, the thermometer invariably stands at 53° F.

1. That in all cases there is a progressive increase of temperature as we descend, after the zone of variable temperature is passed.

2. That this increase, though constant, is not regular, but that it differs—

(*a*) at the same depths within limited areas;

(*b*) at the same depths at different periods.

3. That these irregularities may probably arise—

(*a*) from a difference in the conductibility of various rocks, some becoming heated and growing colder more rapidly than others;

(*b*) from chemical action, as of copper sulphides;

(*c*) from the presence of subterranean hot-springs.

A curious proof of the different conducting powers of rocks occurred at the observatory at Armagh, where the astronomer found continued errors in the results of his observations, which were unaccountable on the supposition of inaccuracies in working detail. This led to an examination of the building itself, and it was found to be built upon the junction of two beds of rock of very different natures, the one to some extent pervious[1] to moisture, the other not. When after continued rains the one rock was charged with water, it became a better conductor of heat than the other, and, expanding, tilted the observatory slightly, allowing it to resume its former position when the rock became again dry. In consequence, of these movements the observatory was shifted from the junction of the strata, and no such inconvenience has since been felt.

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[1] L. *incrementum*, the act of increasing.

2. Volcanoes. (*a*) *Definition, etc.*—A volcano consists of a hole or vent from which heated matter such as molten rock (*lava*), ashes, mud, gases, etc., are thrown out. Round this vent the ejected[2] matter gathers as a cone of greater or less dimensions according to circumstances, sometimes forming gigantic mountains as in the Andes, and at others only slight elevations scarcely worthy the name of hills. The vent is usually in the shape of a cup, and is hence called the *crater.*[3]

(*b*) *Varieties of Volcanoes.*—The usual character of a volcano is that of a hill or mountain, from which lava[4] flows and ashes are thrown out; but there are other varieties of less importance and size, such as *Mud Volcanoes*, or *Salses*, which eject mud; *Solfataras*, and *Fumeroles*, which simply emit sulphureous and other gases and smoke.

(*c*) *Activity of Volcanoes.*—Volcanoes cannot be considered as permanent features of the earth's surface; for though geology assures us that volcanic action has been prevalent through all the past eras of the globe, yet the regions where this activity is displayed are continually changing. Whole districts where now no sign of such action occurs bear evidence of having been formerly subjected to its power; and all those regions where volcanic action displays itself at present, have become seats of such action within comparatively recent times, speaking geologically. Even confining ourselves to the phenomena of volcanoes as they at present exist, we see them in every stage of existence: some, as Etna and Vesuvius, are in full activity; others seem to be half worked out, like Teneriffe; and others, again, appear to be quite extinct, as in the volcanic region of the South of France. Sometimes it happens that a volcano which has for ages appeared to be extinct, breaks suddenly forth, and again becomes active. Perhaps the best known case is that of Vesuvius, which had never been considered as active, no instance of an eruption[1] being known for seventeen hundred years. In A.D. 63, it first showed signs of activity by an earthquake, and in A.D. 79, the mountain burst forth into a fearful eruption, resulting in the burial of Herculaneum and Pompeii, two populous and wealthy cities lying at its foot. Since this time it has fully borne out its character as an active volcano by frequent eruptions.

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[1] L., *per*, through, and *via*, a way. Affording a way or passage through. [2] L., *e*, out of, and *jectum*, thrown. [3] L., *crater*, a bowl, or cup. [4] It., *lava*, flowing like water. The molten rock ejected by volcanoes.

We may divide volcanoes into *active* and *extinct*, and it is important always to preserve this distinction, as by so doing we are enabled to map out the areas over which volcanic energy is in full sway, and those in which it is decaying or already extinct.

(*d*) *Origin of Volcanic Cones.*—This is a subject which belongs more closely to geology, than to our present subject, and can only be briefly noticed here. Two theories have been propounded to account for the formation of volcanic cones, known respectively as the *Elevation Theory* and the *Eruption Theory.* The first supposes the cone to be formed by the swelling up of the level-lying rocks into a bubble-shaped mass, which finally bursts at the top, forming a crater; such craters being known as craters of elevation.

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[1] L., *e*, out of, and *rumpo*, to break. A bursting forth.

The Eruption Theory considers the cone the result of the ashes and lava accumulating round the crater as a centre, and this theory is the one now accepted by most geologists. Numerous instances of so-called "craters of elevation" have been cited, particularly the formation of Jorullo in Mexico, in the year 1759, a mountain 1695 feet in height, which was formed nearly entirely in one night; but this, like other cases, has served to afford conclusive proofs in favour of the theory it was intended to upset.

(*e*) *Eruptions.*—It not unfrequently happens that an eruption is preceded by earthquakes and by rumbling noises like distant thunder; occasionally, peculiar weather presages the coming change, but generally it breaks forth without warning. The commencement of an eruption is often attended by lamentable consequences from the sudden melting of the snows upon the mountains where they are sufficiently high. Thus in 1803, the enormous bed of snow upon Cotopaxi, in the Andes, was melted in one night; and in 1797 the melted snow from Tunguaragua, in the same range, mixed with earthy matter into a mud, rolled down the sides of the mountain filling valleys a thousand feet wide to a depth of six hundred feet.

A cloud of smoke usually rises over a volcano during an eruption, and enormous quantities of ashes are projected, and carried by the wind to immense distances: for instance, the ashes of Coseguina in the Andes fell at a distance of 1200 miles. Fragments of rock are also shot out of the crater like shells from a huge cannon, and are hence known as "volcanic bombs:" a block weighing ten tons has been thrown to a distance of nine miles by Cotopaxi. Lava, or molten rock, flows down the mountain sides in immense volumes. Thus, in 1851, Tomboro, in the East Indies, ejected lava sufficient to make three mountains the size of Mont Blanc; and Skapta Jokul, in Iceland, during 1783, poured forth a quantity equal in volume to the amount of water discharged by the Nile in a year.

Many volcanoes discharge no lava, but throw out ashes only: those of South America are mostly of this character, though lava streams are not unknown even there. As a rule, it may be stated that lava is not poured from craters where they are very high; in Etna, for instance, it bursts from the sides of the mountain, ashes only being thrown from the highest crater. Another feature in eruptions is, that two volcanoes in the same group are seldom active together, the force finding vent in one spot appearing to ease the other members of the group. It has also been noticed that during eruptions earthquakes are rare in volcanic districts, and that when a long period of repose takes place, violent earthquakes are not uncommon. This fact, if generally shown to be true, would prove the doctrine that has been advanced, of volcanoes acting, as it were, as safety valves for the subterranean force.

New islands have been formed by volcanic eruptions, as in the North Pacific, among the Aleutian Archipelago, where one was elevated to several thousand feet above the sea; it having been first noticed in the year 1796. Also in the Mediterranean new islands have been formed, as Graham's Isle in 1831, which however was washed away by the sea in nine months, and is not now visible.

(*f*) *Distribution of Volcanoes.*—The first and most striking fact in the distribution of volcanoes is their nearness to the sea. Only in one instance are they known to occur in the interior of a continent—in the range of Thian Shan, in Central Asia; but even in this case a doubt is thrown on their being true active

canoes. Jorullo, in Mexico, 120 miles from the
st, is considered quite exceptional in being so far
ind.

The actual number of active volcanoes cannot be
ted with any degree of accuracy, different geogra-
ers taking different views of the activity of the
ne volcanoes, and in other ways variously estima-
g the number. From 300 to 400 principal cones
y be taken as the amount in round numbers, and
these fully one half occur on islands.

Professor Ansted gives the following table of their
tribution.

	Principal Cones.
Atlantic Ocean, Northern part	10
,, ,, Central part	10
,, ,, Southern part	3
Gulf of Mexico—West Indian Islands	10
Mediterranean—Sea and Coasts	5
Red Sea, and African Coast adjacent	2
Indian Ocean—West side	3
Asiatic Continent	5
Asiatic Coasts and Islands—Southern part	75
,, ,, ,, Eastern part	110
Eastern Archipelago and Pacific Ocean	16
America, Northern Series	45
,, Central Series	45
,, Southern Series	54
Antarctic Land	3
Total,	396*

The arrangement of volcanoes is peculiar; for in-
nce, the basin of the Pacific is roughly circled by
ast chain of volcanoes. Commencing on the North
nerican coast, we find active volcanoes at intervals
we come to Mexico, where they begin to occur in

Herschel gives only 225, but says 900 have been estimated
occur in the *Nicobar* and Philippine Islands.

force; thence through South America the whole range of the Andes is more or less volcanic. Crossing now to the eastern side, we find volcanoes appear in New Zealand, New Caledonia and, thence, running northwards, through New Guinea, we come to the great band of volcanoes in Java and Sumatra, where the line separates into two, one branch running into the Indian Ocean by the Nicobar Islands and terminating at Barren Island, in the Bay of Bengal: the other, bearing eastwards, runs through the Philippines to Japan, thence by the Kurile Islands to Kamtchatka, and so by the Aleutian Islands to the American continent. Thus we see that the Pacific basin is enclosed as it were by a huge girdle of volcanoes, which includes about two-thirds of the whole number of active volcanoes known. In this circle are found some of the grandest examples of volcanic energy: the vast mountains of the Andes with active vents 20,000 feet above the sea, throwing up flames 3000 feet above their craters, as in the case of Cotopaxi; the Kamtchatkan volcanoes, little inferior in magnitude, and the Javan region, containing more volcanoes than any area of the same size in the world, all lie within it.

A splendid cluster of active volcanoes lies in the centre of the Pacific ocean—the Sandwich Islands; Hawaii, the principal island of the group contains four fine peaks, *Mauna Kea* and *Mauna Loa* being the most important. The crater of *Kilauea*, in the latter mountain, is considered the largest and finest known. The Marquesas and the Society Islands are volcanic, as are also the Galapagos Islands, off the coast of equatorial America.

In the Atlantic we find volcanic islands in Jan Mayen Island and Iceland, which latter contains *Hecla*, a mountain almost continually in a state of eruption. The Azores are another group of such islands, *Teneriffe* being in a state of partial activity. The Canaries are volcanic, but contain no volcano in actual eruption, though it would scarcely be correct to say that they are extinct. The Cape de Verdes, more to the south, have one active volcano, and the Islands of St. Helena and Ascension are volcanic, as are also Trinidad, and some of the West Indian Islands.

Two very important volcanic regions occur in the Mediterranean; the one including Italy, Sicily, and the Lipari Islands, the chief centres of action being *Vesuvius*, *Etna*, and *Stromboli*, the last almost continuously emitting lava. The other region includes part of Greece and the Archipelago, and possesses a fine group of active volcanoes in the Kaimeni Islands, of which *Santorin* is the chief.

A larger volcanic district is that of the southern portion of the Red Sea. It extends over some 10,000 square miles of country, and contains *Jebel Teah*, an active cone; fine craters occur at Ras Khor Ali.

Several districts in Europe, as Auvergne in France, and the Eifel in Germany, are of volcanic origin; but as the volcanoes are extinct, their consideration belongs more to the science of geology than to our present subject.

(*g*) *Mud Volcanoes.*—Mud volcanoes occur both in volcanic regions and in places where no sign of volcanic action exists, save what is afforded by their presence. In the latter case, they appear to illustrate a subdued phase in the volcanic force; hot springs under similar conditions point to the same conclusion. Mud volcanoes are usually of but very slight elevation, but instances are known of considerable hills being formed by them, one in the peninsula of Kertch having a height of 250 feet.

The activity of these volcanoes is but slight, and the mud simply runs over the edge of the crater. The matter thus ejected varies in temperature from many degrees above boiling-point to the ordinary temperature of surface water in the district. Bubbles of gas burst through the mud, and vapours occasionally arise from it. The solid material of the mud, in many cases at least, is not derived from a great depth, as fragments of vegetable matter, and minute shells (*foramenifera*) not unfrequently occur in it.

The best known series of mud volcanoes, apart from those occurring in true volcanic regions, is that which, commencing in the Crimea, runs parallel with the Caucasus to the Caspian Sea, and has been traced at intervals for more than a thousand miles. Along the northern slopes of the Himalayas and into China, they have also been discovered.

3. Earthquakes. That there is an intimate connection between the origin of volcanoes and of earthquakes is shown by the fact that earthquakes occur in greatest number in volcanic districts. They are not, however, confined to these districts, but sometimes happen at great distances from them, as in the case of Comrie, in Perthshire, where hardly a year passes without at least one shock being felt.

(*a*) *Phenomena attending Earthquakes.*—Earthquakes generally happen unexpectedly; but strange noises in the earth, as of clanking of chains, deep muttered thunder, sharp ringing cracks, rumbling of carriages, often forebode and accompany them. Heavy falls of rain at unusual seasons, a peculiar thickness of the atmosphere, sudden gusts of wind, and electrical phenomena also in many cases have happened, and the domesticated animals have appeared strangely alarmed before the shock, and in some cases men have experienced sensations of dizziness and sickness. These phenomena show us that the causes producing the earthquakes are often in operation some time before the shock is felt. The effects upon animals and men are doubtless due to slight movements of the ground. In some cases, as in Caraccas, noises like thunder have been heard over great areas, without being followed by an earthquake.

(*b*) *Nature of the Shock.*—There are three kinds of earthquake shocks, distinguished as the *undulatory*, the *perpendicular*, and the *horizontal*.

The undulatory is the form in which by far the greatest number of earthquakes occur. The shocks are propagated through the earth as undulations or waves, which travel either in parallel lines or in circles spreading from a centre and becoming less as they proceed further from that centre. These earthquakes are sometimes so slight as only to set the church bells ringing, or, as the American poet has it—

> "That young earthquake t'other day,
> Was great at shaking props."

But this class of earthquake is by no means always so gentle; for the great earthquake which destroyed Lisbon in 1755 was of this character. The area disturbed by this earthquake was four times the extent of Europe. It was felt in Sweden, on the Baltic, in Algiers, in the West Indies, and in Canada; and the waves were estimated as travelling at the rate of twenty miles a minute.

The perpendicular shocks are less frequent than those just described; but are usually attended with much more serious results. They have much the character of an explosion, bodies in the vicinity of the shock being violently projected into the air. One of the most terrible examples of this class of earthquake is that which took place at Riobamba in the year 1797, when trees, rocks, and shattered buildings were thrown into the air: some of the inhabitants shared the same fate, and were hurled hundreds of feet high, falling upon a neighbouring hill.

The horizontal motion is of rarer occurrence than either of the two movements mentioned, and is the most destructive in its effects. The motion seems to be a combination of the other two, and the ground is twisted horizontally. The shocks in Calabria, in the year 1783, were of this character; 200 towns and villages, and a hundred thousand persons, were destroyed, and fields were found to have exchanged positions. In this kind of earthquake great fissures are often formed in the rocks, some of which remain permanently gaping, while others close again. The production of fissures, however, is not confined to any particular class of shock, though the last described seem to be most favourable for their production; but, as the sad records of many places show, fissures open during undulatory earthquakes, as in the case of Jamaica, where, in the year 1692, Port Royal was destroyed, and many people were swallowed up in the cracks which were continually opening and closing.

(*c*) *Area over which Shocks are felt.*—The extent of ground disturbed by different earthquakes varies very greatly, and is not necessarily proportionate to the severity of the shock. The Lisbon earthquake was felt over a district extending from Bohemia to the West Indies in one direction, and from Algiers to Sweden in the other; while the Calabrian earthquake above mentioned, though equally violent, was confined to an area of 600 square miles. Earthquake shocks are often propagated in circles or ellipses, though, singularly, the point of greatest disturbance is not one of the foci of the ellipse. It has been found that earthquakes felt over a distance of 1000 miles, only occur once or twice in a century; those whose diameters do not exceed 500 miles, are much more frequent; and small earthquakes extending over not more than 150 miles, are of almost daily occurrence.

(*d*) *Direction of Undulations.*—The undulations produced by earthquakes generally follow the same direction in the same district. Thus in Scandinavia, the direction is about south-west; and in Great Britain it is nearly the same. In Spain, the direction is about south-east, and in the Alleghanies it is towards the north-west.

(*e*) *Periods at which Earthquakes most frequently occur.*—From observations upon the whole of the known earthquakes, it appears that there is a certain recurrence of periods at which great numbers take place. Thus, in a given century there are usually two periods when shocks are greatest, one in the middle of the century and one towards the end; of these the former is characterised by the most severe shocks. Some centuries are much more strongly marked by earthquake phenomena than others; last century is an illustration of one in which this energy was largely developed, and the fourteenth century of one in which it was very feebly represented.

Attempts have been made to show that earthquakes are more frequent at some seasons than at others; and it appears that autumn and winter are marked by the prevalence of shocks, while spring and summer are comparatively exempt from them. In some districts, however, as in the eastern Mediterranean region, the influence of the seasons seems to be unmarked, earthquakes occurring indiscriminately at all times.

It has also been attempted to be shown that the periods of new and full moon are marked by the occurrence of earthquakes, and that the greatest numbers happen at the former period. These suggestions, though very important, do not however as yet rest upon a sufficiently firm basis to allow of our accepting them as established facts.

(*f*) *Distribution of Earthquakes.*—While there is no volcanic district which is exempt from earthquake action, there are many regions, more or less clearly determined, far removed from such action, which are nevertheless characterised by decided earthquake phenomena; and these will now be briefly pointed out. One remarkable fact must, however, be noticed before entering upon this subject, and that is, the occurrence of districts, in regions subject to earthquakes, where no shock is ever felt. Even when earthquakes happen in the vicinity, they pass these districts without affecting them, and resume upon the other side their usual features. Many such areas are known in Peru, and they are called by the natives *bridges.* In Central Asia, such an area occurs between two earthquake regions. The cause is to be sought in the character of the rocks composing the "bridges," but the subject is not satisfactorily cleared up.

To return to a consideration of the earthquake regions. In Europe, as elsewhere, the chief seats of earthquake energy are the volcanic districts; but a very important one is that which extends from Portugal to the Azores, Canaries, and Madeira, and is continued into Northern Africa. Another centre includes the British Islands; further north, one embraces the Shetland and Faroë Islands and South Norway, and another includes part of Sweden and Lapland. The Alps and Pyrenees are included in a band of intense action which, centered in northern Italy, extends through France and Germany, and westwards into Holland. The Carpathian and Balkan ranges, and, indeed, the whole of the mountain system of the Old World, are more or less subject to this action.

In Asia, an earthquake band stretches from Persia to India, in which latter country the action is very severe, especially in the north. China has also a centre of earthquake energy, and another stretches from Further India northwards along the line of volcanic disturbance.

Africa is exempt from earthquake action, except in the north and along the Red Sea, and in the extreme south.

America has its earthquakes coincident with the mountain chains, the chief band being necessarily that of the volcanic ranges; but severe shocks are felt in the Alleghany Mountains. The Mississippi and Missouri and the St. Lawrence basins are also subject to earthquakes.

Australia is undisturbed by earthquakes, except n the west, where slight shocks are not unknown. Tasmania is also occasionally disturbed by them; and New Zealand, possessing, as it does, a volcanic region, is frequently and violently shaken.

In the Atlantic, between Capes Palmas and St. Roque there is believed to exist an area of volcanic and earthquake disturbance; ships having several times experienced shocks as if striking on a rock, when soundings have shown them to be in deep water.

4. **Movements of the Land.** (*a*) *Direct Proofs.*—It has always been one of the first principles of geology that the land is not stationary, but has been many times far beneath the waves, while continents have occupied the areas now covered by the ocean. These movements were referred entirely to earthquake action, and were considered to be sudden and strongly marked. But it is now known that large areas are at the present moment slowly and imperceptibly rising from the sea, and others as gently subsiding beneath it. Long-continued observation alone has determined the truth of this startling proposition, and it is now accepted by all geologists as an established fact. So slow is this motion, that it probably in few cases exceeds three or four feet in a hundred years. Norway and Sweden are now known to be undergoing a process of upheaval north of the district of Scania, and of subsidence to the south. In the intricate channels of the Baltic coast, rocks which formerly were too far beneath the water to afford any obstruction to navigation are now so near the surface as to be dangerous.

In the south, the distances from the sea of large rocks have been measured, and subsequent examinations have shown them to be nearer the water than formerly. In the first case elevation, and the last depression, was the cause of the change.

Greenland is undergoing a slow depression, as is proved by the fact that the staples driven into the rocks by the early settlers to fasten boats to, are now some distance below low-water mark. So well known is this movement, that the Greenlander never erects his house close to the sea, for this very reason.

Since the above discoveries have been made, proofs of the gradual elevation and depression of land masses in many parts of the world have been obtained; many of them in volcanic districts, as in South America, which continent is believed to be gradually rising, at least on its Pacific coast.

(*b*) *Coral Reefs.*—Mr. Darwin has shown that a remarkable connection exists between these movements and the distribution of coral reefs. To understand this, we must enter more fully into the origin of those reefs than we have hitherto done. The reef-building coral animal can only live within a certain moderate distance (about 25 fathoms) from the surface;[1] but it is well known that very many reefs have a much greater thickness. It is, therefore, concluded that, at the period when the lowest portion of the reef was building, the foundation upon which it was erected stood at a higher level; and as it slowly sunk, the coral animals kept pace with the movement by building continually upwards. This accounts for e immense thickness of some reefs, and for the eepness of their sides.

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[1] It has recently been thought that, as living corals have been dredged from great depths, this theory would not hold good; but Professor Duncan, F.R.S., informs me that the fact of corals living at such depths has long been known, and that they are not *reef-building* species.

There are three distinct varieties of coral reef; mely, *fringing-reefs*, which are of no great size, and mply fringe the shore; *barrier-reefs*, which follow e coast line, often at a considerable distance from , and are often of immense length and great thickss; and *atolls*, which usually take the form of rings closing a basin of water called the *lagoon:* they are ually of great thicknesses. The manner in which r. Darwin shows how these reefs are the result of e sinking of the land, will be readily understood by ference to the following diagram, in which Fig. 1

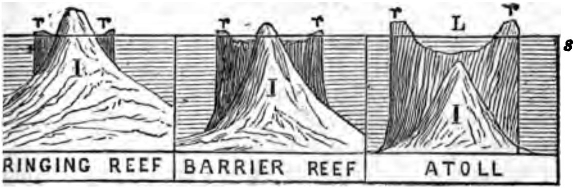

FIG. 1. FIG. 2. FIG. 3.

presents a fringing-reef, Fig. 2 a barrier-reef, and ig. 3 an atoll; I representing in all cases the island on which the reef is built; *r* representing the reef; the lagoon; and *s*, *s* the sea-level. The island is own in three successive stages of submergence, and e different kinds of reef are shown as the conseence of this sinking; the barrier-reef growing t of the fringing-reef, and the atoll resulting from e barrier-reef.

Now, these varieties of reef do not all occur in e same area, atolls being confined to certain disicts, and so on. From a study of the distribution reefs, it is rendered extremely probable that where e Pacific Ocean now lies a great continent existed a comparatively recent period in the world's history, and by its gradual submergence has given rise to the myriad coral islets that gem the bosom of the ocean. Over the volcanic district of the Pacific not a single atoll exists: this is probably an area of elevation. Another area of atolls connects the Malabar coast of India with the island of Madagascar by the Laccadive, Maldive, and Chagos Islands.

CHAPTER VII.

ATMOSPHERE AND CLIMATE.

A. ATMOSPHERE.

Size, Weight, and Pressure.—The earth is enveloped in a body of invisible gas which is known as the *atmosphere*,[1] and the material composing this atmosphere is called *air*. Air being highly elastic is pressed by its own weight into a less bulk, hence it is densest at the surface of the earth, and becomes more attenuated, or thinner, in its higher regions. So elastic is the air, that at the height of 18,000 feet, or three and a half miles, its density is only one-half; and at 36,000 feet, or nearly seven miles, it is only one-fourth of what it is at the sea level. At the elevation of forty-five miles, the air would be almost imperceptible; but there is little doubt that the atmosphere extends to at least 300 miles from the earth. The pressure of the atmosphere is about fifteen pounds (14·7) on every square inch of surface; or 26,345,088 tons on every square mile. This gives the total pressure sustained by the whole earth as 5,189,982,336 million tons.

The Barometer.—The pressure of the atmosphere at any particular place is measured by means of an instrument called a *barometer*,[1] which consists of a tube from which the air has been exhausted: this tube is closed at one end, and the open end is inserted in a cup of mercury. The atmosphere pressing upon the mercury in the cup forces it up into the tube (there being no pressure there) until the weight of the column of mercury equals the pressure upon the surface outside the tube. This height is 29·9 inches, but if water is used, the column would be about thirty-three feet high. In other words, a column of mercury nearly thirty inches in height, and a column of water thirty-three feet high, press downwards with a weight equal to about fifteen pounds on the square inch. As we ascend, the pressure of the atmosphere decreases, and the mercury falls in the tube; hence the barometer can be used to determine the heights of mountains.

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[1] Gr., *atmos*, air; and *sphaira*, a sphere.

Composition.—Air, dry and pure, is composed of two invisible gases, *oxygen* and *nitrogen*, mixed together and not chemically combined. The proportions are twenty-three parts of oxygen to seventy-seven parts of nitrogen. In its natural state, air is always mixed with other substances; vapour of water is the most abundant of these, and then come carbonic acid, and other matters of less importance. Although animals are continually taking oxygen from the atmosphere and breathing carbonic acid into it, yet the proportions given above remain unchanged. Air in valleys and on mountains, and even that enclosed in vessels buried for centuries is always precisely the same in composition. Why this is so is not satisfactorily explained. It has been thought that the proportion is maintained through the agency of plants, since they give out oxygen and take in carbonic acid; but this is a very insufficient cause.

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[1] Gr., *baros*, weight; and *metron*, a measure.

Relations with Light. 1. *Colour.*—The sun's rays consist of two distinct parts, the one producing light, the other heat. The rays of light are themselves made up of distinct portions, each possessing its own peculiar colour—red, orange, yellow, green, blue, indigo, and violet; the combination of these rays forms white light. If we could strain out all, save one particular class, it is evident that the remainder would possess a distinct colour. Air allows all the coloured rays to pass with almost equal facility; it is, however, never quite dry, but contains water as invisible vapour. Now water absorbs all the coloured rays, save blue, hence the colour of the sea; and the watery vapour absorbs the same rays, the result being the blue sky;[1] so that whether we look upon the sky overhead, or examine the ocean beneath, we are equally gazing upon huge masses of water. In desert regions, and at great elevations, the sky appears much darker; indeed, from the tops of high mountains it looks almost black, owing to the absence of vapour. The blue sky, then, is the result of the absorption of the other coloured rays of light by the vapour; and it is possible to get above most of this blue vault, even as it is possible to get above most of the cloud region.

The brilliant colours of sunrise and sunset are due to the same cause, namely, the absorption of certain colours from the rays of light, reflected from the sun, but why these colours should vary so much in beauty at different seasons and in different places is not yet determined.

(2) *Reflection,*[2] *Refraction,*[3] and *Absorption.*—Let us trace the course of a ray of light from the sun. It travels in a direct line until it meets the earth's at-

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[1] This subject is intimately connected with *polarisation*, which cannot be here discussed. [2] L., *re*, back; and *flecto*, to bend. [3] L., *re*, and *frango*, *fractus*, to break.

mosphere, when a portion is turned back, or *reflected*, as from a mirror. The remaining portion is bent or *refracted* on entering the atmosphere, and as it proceeds, the air through which it travels continually grows denser, and the ray becomes more and more bent. During the whole of its passage through the air small portions have been *absorbed*, and others have been scattered or *dispersed*.[1] Hence a ray which would reach the earth in a direct line, if there were no atmosphere, suffers great changes. Part is destroyed by absorption, part turned back again by reflection, the remainder reaches the earth in a bent line, and instead of arriving as a distinct ray, is, as it were, frayed out, and illuminates a greater space than it otherwise would. On reaching the earth, the ray is partly absorbed and partly reflected again, lighting up the surface of the earth. The faint form of the circle in the crescent moon is rendered visible by light reflected from the earth. If there were no atmosphere there would be no dispersion of light, and all things would be either exposed to the full blaze of light, or plunged in intense darkness. Shadows would be as black as night, deep valleys would be always buried in darkness.

If the rays fall perpendicularly, 8000 out of 10,000 reach the surface of the earth; 2000 being absorbed. The greater the inclination at which the rays fall, the greater the number absorbed. If the direction be horizontal, only five rays out of 10,000 reach the observer. This explains why the rising and setting sun can be looked at without inconvenience.

(*a*) *Twilight.*—If there were no atmosphere, day would be succeeded by night instantly on the sun setting. The atmosphere refracts, or bends the rays of light, and this bending is greater as the angle is less. The sun in consequence always appears to be higher in the heavens than it really is, for the rays of light are bent upwards towards the perpendicular. When the sun reaches the horizon, it still *appears* to be some distance above it; and when it seems to us to set, it is really below the horizon, but is visible, because *the rays of light coming from it are bent upwards.* After sunset the refraction still brings sufficient light upwards to partially illuminate the earth, and this dim light is *twilight.* When the sun is more than from 15° to 20° (according to the latitude) below the horizon, the rays of light cannot be refracted so as to produce twilight, and night may be said to have set in. Within the tropics, where the sun descends almost perpendicularly, twilight is very short; but as we ascend to higher latitudes the sun declines more obliquely, and takes longer to reach 20° below the horizon: hence the longer twilight of these regions. In the arctic region the sun appears some days before it would otherwise be seen, and remains above the horizon longer before setting than would be the case if there were no atmosphere.

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[1] L., *di*, apart; and *spargo*, to scatter.

(*b*) *Mirage.*—The word *mirage* is applied by the French to those peculiar atmospheric effects due to the different densities of the lower portions of the air, and to reflection and refraction. We cannot here describe in detail the various illusions thus produced, nor give their explanation, as it would lead us beyond the limits of an elementary work, but we will briefly refer to the most usual phases under which mirage is seen. Perhaps the most common form is the semblance of sheets of water, sometimes still, sometimes ruffled by waves. This is very frequently seen in hot desert regions, but is by no means confined to them. We have had opportunities of observing them under both aspects, and have witnessed in the Fen-*land mirages* as clearly defined and deceptive as those of Africa. In them the trees and surrounding objects were reflected as accurately as from the gleaming surface of a pond.

Sometimes objects are reflected horizontally, and buildings are seen from points of view from which they are ordinarily hidden by hills.

In other cases the refraction is so great as to bring into view objects hidden below the horizon. Thus in the summer of 1870, the author, with one of his colleagues, saw from the battlements of Croyland Abbey, the town of Boston and the whole of the Wash, as it were tilted up into the air; steamships and sailing vessels were plainly visible. Under ordinary circumstances, neither Boston nor the Wash are discernible from Croyland. The time was sunset, and, as so often happens in such cases, heavy rains succeeded. Again, in 1871, in travelling between Spalding and Boston, the Lincolnshire coast was plainly visible, although the country is so flat, that the sea-banks effectually shut out the view of the water, even at the distance of a quarter of a mile from the shore. This was also at evening, and rainy weather ensued.

Sometimes the refraction is imperfect, owing to strata of air of different densities intervening. In this case the image is distorted. In May, 1869, we saw a very perfect instance of this kind of mirage in the Red Sea, when the town of Mocha was seen slightly elevated above the horizon, and apparently shattered by an earthquake shock.

Again, objects may appear suspended in the air, immediately above their actual position. Captain Scoresby saw his father's vessel in the air in an inverted position. We have seen a village church inverted (Billinghay, Lincolnshire), with the spire of the actual church and the spire of the image touching. This was in September, 1871; again at sunset. The body of the church was hidden by white smoke, rising from burning stubble, and from this the building was reflected in an inverted position. It was, as is generally the case, of great size; the spire appearing to be almost a mile in length, with the other parts of the building proportionably magnified.

(c) *Halos, Mock-Suns.*—The circles of light which so often surround the sun, and less frequently the moon, in polar regions, owe their existence to much the same causes that produce mirage, namely, to the reflection and refraction of light by strata of different densities. The circles are called *halos*, and several are often visible at once; sometimes concentric,[1] sometimes intersecting.[2] Mock-suns, or *parhelia*,[3] are also common in these latitudes. *Paraselenes*,[4] or mock moons, are less frequent; a very fine one was seen in England in the winter of 1871.

(d) *Rainbows* are caused by the decomposition of light by drops of water. The colours are in the following order, reckoning from the inside of the bow: violet, indigo, blue, green, yellow, orange, red. If the light be intense, a second bow is formed outside the first, with the colours reversed and fainter in tint. The rays of light in the principal bow are refracted on entering the rain-drop, reflected from the inner surface, and again refracted on leaving the drop. During this process the light is decomposed. The outer bow is somewhat more complicated in its formation, as besides being twice refracted, the light is twice reflected from the inner surface of the drop, the colours appearing fainter from part of the light being absorbed at each refraction and reflection.

Rainbows are sometimes produced by the moon; but these *lunar*-rainbows are rare, and are generally white. Bows are often formed in the spray of waterfalls and fountains, and indeed in any circumstance where drops of falling water are produced in bright sunlight.

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[1] L., *con*, together, and *centrum*, a centre; having the same centres. [2] L., *inter*, through; and *sectum*, cut. [3] Gr., *para*, about; and *helion*, the sun. [4] Gr., *para*; and *selene*, the moon.

Rainbows always occur opposite to the sun, and when observed from mountains are perfect circles. They are usually seen against a bank of clouds, but occasionally have only blue sky behind them.

Relations with Heat.—Let us now turn to the dark heat-giving rays mentioned above (p. 160). Dry air is as transparent to heat as to light; allowing it to pass through without becoming sensibly warmed. Of the heat that falls upon the surface of the earth, part is absorbed, and warms it, and the rest is reflected back again into space. That the air is not itself warmed by the passage of heat through it, is at once evident when we remember that in clear frosty weather, it may be thawing rapidly in the sun, while it is freezing sharply in the shade. If the air were heated by the sun's rays this could not happen, for the air in the shade would be warmed by the particles of hot air in the sunlight. Air can, however, be heated by *conduction:* that is to say, the earth being heated, communicates its warmth to the air above, which in its turn, warms the immediately overlying air. During this process, heat is, however, destroyed. The heated earth cannot make the overlying air as hot as itself. Hence it follows that the higher the position above the earth, the lower will be the temperature.[1] We have now shown that air is not warmed by the sun's heat directly, *but by the heat transmitted by the earth to the air above.* The decrease of temperature with altitude, is generally about 1° for every 300 feet.

The heat arriving at the earth's surface is not, however, the whole of that emitted by the sun; for though the air itself is perfectly transparent to heat, *the moisture contained in it is not*, but on the contrary, is opaque to heat, and stops off a large quantity. It is very important to bear in mind this atmosphere of vapour, as it exercises most important influences. Indeed we may say that *there are two atmospheres, the one composed of air, the other of vapour.*

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[1] Heated masses of air rising to the higher regions of the atmosphere lose their heat in expanding. This is another, and an important cause of the low temperature of those regions.

Movements.—The movements of the atmosphere are of three kinds. (1) *Aërial Tides*, caused by the same influences that produce oceanic tides. (2) *Barometrical Oscillations*, or variations in the pressure of the atmosphere, so called from being measured by the barometer. (3) *Winds.*

1. *Aërial*[1] *Tides.* Everything that we have said respecting the origin of the tides is as applicable to the atmosphere as to tho ocean, with this exception, that the disturbing causes are not continents, but currents of air produced by local influences. These currents are generally of sufficient magnitude to entirely mask the tidal movements. Within the tropics, where the disturbing causes are slight and regular, these tides are said to have been determined with considerable accuracy.

2. *Barometrical Oscillations.*[2] The barometer does not stand at the same height throughout the day. When the pressure diminishes, the mercury in the instrument falls, and hence any variation in the pressure is immediately registered by the height of the barometer. The barometer attains its maximum twice in twenty-four hours, and falls to its minimum twice also. The two maxima occur at half-past nine in the morning, and at half-past ten in the evening; the two minima are at half-past three in the morning, and half-past four in the afternoon. That is, the

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[1] *L., aërius*, belonging to the air.

[2] L., *oscillatio*, a swinging movement.

points of least pressure occur at the hottest and coldest parts of the day; and the points of greatest pressure at the times of mean daily temperature. In other words, two waves pass over a given place each day, the passage of their crests causing the greatest, and the passage of their troughs the lowest range of the barometer.

One of these waves is owing to the action of the sun's rays upon the air atmosphere; the other to its action upon the vapour atmosphere.

The sun's rays falling upon the earth during the day, heat the air, which, expanding, rises and flows over towards those regions where night prevails, and where the air is colder and denser. Hence there is less air over any place at the hottest part of the day (the afternoon), and the barometer is at its lowest; and most air at the coldest period of the day when the barometer stands highest.

"The barometer is influenced to a large extent by the elastic force of the vapour of water invisibly suspended in the atmosphere, in the same way as it is influenced by the dry air. But it is probable that the vapour of water exerts a pressure on the barometer in another way. Vapour tends to diffuse itself equally through the air; but as the particles of air offer an obstruction to the vapour, it is accumulated or pent up in the lower stratum of the atmosphere about 9 or 10 a.m., when evaporation is most rapid, and, being impeded in its ascent, its elastic force is increased by the reaction, and the barometer consequently rises. When the air falls below the temperature of the dew-point, part of its moisture is deposited in dew; and since some time must elapse before the vapour of the upper strata can diffuse itself downwards to supply the deficiency, the barometer falls—most markedly at 10 p.m., when the deposition of dew is greatest.

"Hence, as regards temperature, the barometer is subject to a maximum occurring near the period of greatest cold, and the minimum near the period of greatest heat. And, as regards vapour in the atmosphere, the barometer is subject to two maxima and minima of pressure: the minima occurring, the first at 10 a.m., when, owing to the rapid evaporation, the accumulation of vapour near the surface is greatest; and the second about sunset, or just before dew begins to be deposited, when the absolute amount of vapour in the atmosphere is greatest; and the minima in the evening, when the deposition of dew is greatest, and before sunrise, when evaporation and the absolute quantity of vapour in the atmosphere is smallest.

"Thus, taking both causes into consideration, the maximum in the forenoon may be supposed to be owing to the rapid evaporation arising from the dryness of the air and the increasing temperature, together with the overflow of air in the upper regions of the atmosphere from the wave of heat which has been going on for some hours. But as the vapour becomes more equally diffused and the air more saturated, evaporation proceeds more languidly; the air becomes also more expanded by heat, and tends to flow towards the diurnal wave of cold advancing from the eastwards, and the pressure falls to the afternoon minimum. From this time the temperature declines; the air approaches more nearly the point of saturation, and the pressure being further increased by accessions of air from the warm wave, the minimum is attained. As the deposition of dew proceeds, the air becomes drier, the elastic pressure of vapour is greatly diminished; and the pressure falls to the second minimum about 4 a.m." (*Buchan.*)

Winds.—The origin of winds is very simple. Let us consider the earth as covered entirely with water. The temperature would then be directly proportionate to the latitude; the greatest heat at the equator, the most intense cold at the poles, and all places in the *same latitude* would have the same temperature.

The sun's rays, beating upon the torrid zone with intense fervour, heat the air in the manner above described (p. 165). This heating process causes the air to expand, and being then lighter than the cold air above, rises and forms an ascending current. At the same time, the colder, heavier air of the polar regions, flows in towards the equator, and would arrive as north and south winds if the earth were at rest; but in consequence of the diurnal rotation from west to east, the wind lags behind, because it moves over regions which revolve faster than the place from whence it set out. This has been already explained (chap. 3). The winds thus caused arrive with a north-east and south-east movement, and are called Trade Winds, from being so constant, and therefore of such importance to commerce.

At the same time, the ascending currents flow off as upper currents towards the poles; the rotation of the earth causing them to pursue north-westerly and south-westerly courses.

So far all is plain; but on the above supposition, all the winds of the northern hemisphere should be North-east Trades, and all the winds of the southern hemisphere South-east Trades. The south-west winds should flow as an upper current in the northern hemisphere, and the north-west winds as an upper current in the southern hemisphere. These westerly winds would never appear at the surface.

Such, however, is not the case; for the south-west upper current descends to the surface north of the tropic of Cancer, and the north-westerly wind a little south of the tropic of Capricorn. The trade-winds flow as an upper current through the first part of their journey, and only descend to the surface at the points where the westerly winds become surface currents.

The course of a particle of air from the north pole, is as follows. Setting out in the upper regions of the atmosphere, it travels in a southerly direction, until it approaches the northern tropic; it then descends to the surface and travels to the equator with a north-east course. At the equator, it rises again to the upper regions of the atmosphere, and either crosses over to the south side of the equator to descend to the surface at the tropic of Capricorn to take part in the north-west winds of the southern hemisphere, or is whirled back again into the currents flowing north, and again returns to the arctic region.

Why these currents should thus descend and ascend at the tropics, has never been explained.

(*a*) *Calm-belts.*—The consequence of the descent of the currents as above described is, that at the regions where the winds cross, belts occur where there are no winds, or but slight and variable breezes. These are termed the *Equatorial Belt of Calms*, where the Trade Winds rise, the *Belt of Calms of Cancer*, and the *Belt of Calms of Capricorn*, where the Trades and Anti-trades, as these westerly winds are called, interchange. At the poles there are calm belts where the winds ascend.

(*b*) *Trade Winds. North-east Trade Wind.*—This wind extends from about latitude 9° to 26° in the Atlantic Ocean; and in the Pacific, from latitude 9° to 26°. In summer it extends further north; and as the sun goes south, it follows and reaches its most southerly position in winter. This wind is more steady in the Atlantic than in the Pacific, but it is not so constant as the south-east trade wind.

South-east Trade Wind.—This wind extends over a broader space than the above, ranging from about 4° north latitude to 22° south latitude in the Atlantic, and 23½° south latitude in the Pacific. Like the north-east trade, it follows the course of the sun, and owing to the greater extent of water in the region over which it blows, it is stronger and more constant than the trade wind of the opposite hemisphere.

(*c*) *Monsoon.*—In the neighbourhood of the great land-masses the trade-winds become modified in their direction. These modified winds are termed *Monsoons*,[1] and they differ from trade winds in being periodical instead of perennial. The most important monsoon region is that of the Indian Ocean, extending to the north and east of Australia into about longitude 140° west.

When the sun is north of the equator, the immense region of Asia becomes heated to an enormous extent, owing to the great stretches of desert there situated. The heated air thus produced rises, and the south-east trade flows in to supply the loss, and being acted upon by the rotation of the earth and by local causes, is deflected, and becomes the south-west, south, south-east, or east monsoon at different parts of the coast. These winds blow from April to October. When the sun goes south of the equator, the wind follows, and taking up its normal position, blows as a trade wind, though it is called the south-east monsoon. This wind blows from October to April. To the north a monsoon blows generally in a north-east direction.

The changing of the monsoon is accompanied by violent storms of wind and rain, and terrific thunder.

On the West Coast of Africa monsoons occur, the result of the indraught occasioned by the heated continent.

The coast of Brazil also possesses monsoons, and so does the Gulf of Mexico and the Caribbean Sea, and the west coast of America, from California to about 45° south latitude.

(*d*) *Storms.*—The ordinary storms of wind, such as occur in all latitudes, due to some disturbance in the atmosphere, need not be described here; but those fearful storms, known in different parts as *tornados*,[2]

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[1] Arabic, *mausim*, a season. [2] Sp., tornar, to turn.

hurricanes, *typhoons*,[1] and *cyclones*,[2] must be here briefly alluded to. The regions where these storms occur are, (1) the West Indian region, including those islands, and extending northwards nearly to Nova Scotia, and eastwards to about longitude 20° west; (2) the Indian Ocean region, extending from Madagascar almost to Australia, and from 4° to 35° south latitude; (3) the Chinese region, extending from the Ganges to Japan, and from latitude 5° north to 25° north.

The peculiarity of these storms is, that they have a rotary motion, and journey in a spiral line. Their motion in the three eastern regions is in the same direction as that of the hands of a clock, and in the West Indian region in an opposite direction.

It is found that all great storms partake of a circular motion, even the heavy gales of our own coast, such as the one now raging as we pen these lines (January 23rd, 1872).

B. CLIMATE.

Determining Causes.—Climate must not be confounded with weather. The weather changes from day to day, and is proverbially irregular; but climate is constant, for the variations of the weather do not alter the general distribution of heat and moisture throughout the year.

Climate depends upon numerous circumstances, of which the most important are (1) latitude, (2) situation, whether continental or insular,[3] (3) elevation above the sea-level.

Representation.—The distribution of rain and snow we have already described; and it now only remains to examine into the distribution of temperature over the surface of the globe. This is most readily done by means of lines drawn through places having the same temperature. But as a station may have the same annual temperature as another, and yet have that temperature very differently distributed through the year, several series of lines have to be drawn before we can fully understand the details of this great question. These lines receive different names, as follows.

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[1] Gr., *typhon*, a fabled giant. [2] Gr., *cyclos*, a circle. [3] L. *insula*, an island.

1. *Isothermal*[1] *Lines*, such as pass through all places having the same mean annual temperature.

2. *Isotheral*[2] *Lines*, such as pass through places having the same summer temperature.

3. *Isocheimal*[3] *Lines*, such as pass through places having the same winter temperature.

We cannot describe the course of these lines, which may be easily understood by a reference to a map showing their arrangement. But to give an idea of how the temperature varies over the earth at different seasons, we will select two important lines, say the line of 32° F., or the line between which and the poles water remains frozen; and the lines of 77°, or intense summer heat. The months of March, April, and May are reckoned *spring* months; June, July, and August, *summer* months; September, October, and November, *autumn* months; and December, January, and February, *winter* months.

(*a*) *Spring.*—The line of 32° in the northern hemisphere, commencing in the west, lies just north of the peninsula of Alaska, and, curving southwards, runs a little to the south of Hudson's Bay, after which it again bends northward, and just grazing Cape Farewell in Greenland, stretches out into the ocean north of Iceland in the direction of Spitzbergen. In about 70° N. latitude, and 0° longitude, it bends south again so rapidly that it includes the Gulf of Bothnia. Thence it curves a little southward, and stretches across the continents of Europe and Asia in about latitude 59°, cutting off the southern portion of Kamtchatka, and then wending north again to Alaska.

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[1] Gr., *isos*, equal; and, *thermos*, heat. [2] Gr., *isos;* and, *theros*, summer. [3] Gr., *isos;* and, *cheima*, winter.

In the southern hemisphere it is autumn at this time; and the 32° line is so far south that it does not touch any but the circumpolar lands.

The 77° line in the northern hemisphere commences in the west about the twentieth parallel of latitude, and crossing the centre of the Caribbean Sea, dips south in the open Atlantic, so as to exclude the Cape de Verd islands; after which it again bends northward, and crossing the tropic of Cancer, traverses Africa so as to include all the Red Sea except the gulfs of Suez and Akaba. Still pursuing its northerly course, it includes the Persian Gulf and the whole of Hindostan, falling again to latitude 20° as it enters the Pacific from the Asiatic continent.

In the southern hemisphere the 77° line commences in about 5° S. lat. on the west coast of South America, and falls to 20° S. lat. on the east coast; thence it curves north so as to exclude St. Helena, and enters Africa in about lat. 9° S., falling again to 20° on the east coast, and just dipping south of the tropic beyond Madagascar; after which it rises to 20°, in which latitude it enters Australia, and, trending south again, leaves that island on the tropic.

(*b*) *Summer.*—The 32° line in the north has by this time retreated far up beyond the mainland of America, even lying outside Melville Island, but dipping south so as to embrace the north of Cockburn Island, thence stretching far away to the north, through central Greenland and outside Spitzbergen, touching the Old World continent at no point.

In the south, where it is now winter, the line has *travelled* north with rapid strides and lies in wait just now outside Cape Horn, adding fresh dangers to that always dreadful spot.

The 77° lines have also journeyed northwards; the northern line in consequence of the summer's heat; the southern line pushed up by the winter's cold. The northern line commences on the north of the Californian peninsula, crosses America so as to embrace Florida and Georgia; dips south in the Atlantic to the tropic, in longitude 25° W.; and then stretches away north, so as to include the south-east of the Mediterranean, and still north through the southern part of the Caspian Sea, to the south of the Sea of Azof, and so through Asia, which it leaves at Pekin, in latitude 40°.

The southern line has travelled to a little north of the equator in western South America, and to the north of Cape St. Roque on the east. In West Africa it is also north of the line; in East Africa it is only 5° south, and it only just touches the extreme north of Australia.

(c) *Autumn.*—The northern line of 32° is again coming south, and now crosses America so as to exclude Alaska and the southern part of Hudson's Bay. It nearly reaches Cape Farewell, almost touches Iceland, makes a sudden turn south, and embraces north-western Scandinavia and the White Sea, and then bends still further south in Asia, passing just south of Lake Baikal, and cutting the north end of the Island of Sagalien and the peninsula of Kamtchatka, enters the Pacific.

The southern line has retreated from the immediate neighbourhood of Cape Horn, for spring is coming on.

The line of 77° in the north has crept southwards, and occupies much the same position as in spring, but includes the Cape de Verde Islands.

The southern 77° line occupies about the same position as in summer on the west of South America and in Australia; but has curved southwards to Cape St. Roque, in Brazil, to the River Congo, in West Africa, and to north Madagascar on the east.

(*d*) *Winter.*—In the northern hemisphere the 32° line is at its lowest limit. In West America it still hovers round Alaska, but bends south with a great sweep below the great lakes and New York; thence north again south of Iceland, and then south through southern Sweden, and from Berlin through the Caspian, across Asia, and through the Yellow Sea.

The southern line has retreated with summer into the freshness of the antarctic regions.

The northern 77° line has dropped so as to lie just north of the South American shore, whence it stretches in a pretty straight course to Southern India, where it falls slightly, cutting the peninsula of Malacca and north Borneo.

The southern line has at the same time encroached upon South America, and from below Lima drops to the mouth of La Plata; thence in a great bend it cuts off St. Helena, passes through South Africa, from latitude 20° S. on the west to latitude 30° S. on the east, and runs across the Indian Ocean, entering Australia in latitude 22°, trending down to Adelaide, and then north to Sydney.

So far we have traced the distribution of temperature over the globe as a whole, and we will here briefly allude to some important facts not shown in the above sketch. The line of greatest temperature does not coincide with the equator, but lies north of it from about longitude 150° W., across the New and Old Worlds, and falls below it in the island of Borneo. The mean temperature along this line is nearly 84° F., and the hottest portions are the regions around the Red Sea, and the southern shores of the Caribbean Sea.

The points of greatest cold do not occur at the poles, but at some distance from them. Two have been determined for the northern hemisphere, one in the west, called the American pole of cold; the other, in the east, known as the Asiatic pole of cold. The former is situated in about 75° N. latitude, and 100° W. longitude; the latter in about the same latitude, and 95° E. longitude.

The greatest heat registered is 132° F. in the shade in Scinde (*Napier*); the greatest cold −120° at Kiringa in Siberia (*Gmelin*).

Classification.—Climates are grouped, according to the distribution of temperature through the year, into three classes.

1. *Insular Climates.*—Those in which the temperature of summer is but little in excess of that of winter, so named because they usually prevail in islands. The most perfect case being the Friendly Islands, where the difference is only 2°.

2. *Continental Climates*, in which, from being removed from the ameliorating influence of the sea, the difference of the seasons is more strongly marked. Canada is an example of this class. At Quebec, the difference between summer and winter temperature amounts to 58°.

3. *Extreme Climates*, in which the difference is very great. Thus at Yakutsk, in Siberia, the difference amounts to 102°; the winter temperature being −40°, and the summer temperature + 62°.

General Distribution of Temperature.—The southern hemisphere is $3\frac{1}{2}$° colder on the average than the northern, owing to the much greater extent of sea to the south.

If we call the temperature a place would have if latitude alone determined that temperature the mean normal temperature, and then consider those places in which the temperature is above or below that mean, we shall find that the land-masses lying north of the tropic of Cancer have an excess upon their western coasts, and a deficiency along their eastern coasts, while the reverse is true respecting land lying south of that line. This is owing to the direction of the ocean currents. The equatorial currents sweeping to the east in the northern, and to the west in the southern region; the polar currents at the same time clinging to the opposite shores.

CHAPTER VIII.

TERRESTRIAL ELECTRICITY AND MAGNETISM.

Electricity. *Nature.*—Electricity is a *force*[1] which pervades all nature. It is of a twofold character; and, under ordinary circumstances, the two parts of which it is composed are so combined as to neutralise the effect of each other. It is only when a body contains one kind of electricity in excess that its electrical condition is manifest; and the body is said to be *positively* or *negatively* charged, or electrified, according as one or other kind of electricity preponderates. There is a constant tendency in electrified bodies to render themselves neutral by drawing electricity of the opposite kind to their own from some body which possesses it.

Thunderstorms.—The interchange of electricity between the earth and the atmosphere gives rise to thunderstorms. Any disturbance in the atmosphere, whether caused by evaporation, condensation, or otherwise, produces changes in the electrical conditions of the earth and atmosphere. If a cloud, charged with positive electricity, floats within a sufficient distance of the earth, the negative electricity of the earth pulls, as it were, upon the positive electricity, and *vice versâ*;[2]

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[1] Force is a term applied to those causes of motion, such as *heat, light, gravitation.* [2] L., meaning the other way about.

and if this tension becomes sufficiently strong, a discharge takes place, and the electricity rushes from one to the other with inconceivable force and rapidity. During this interchange, heat is produced of so intense a character as to burn the particles of air through which it passes; and the light so produced is seen as a flash, and is called *lightning*. The lightning may travel from the earth to the cloud, or in an opposite direction.

The air on either side the flash rushes in to supply the void caused by the consumed air, and meeting with great force, produces the sound known as *thunder*.

Lightning is seen under three forms: either pursuing a zig-zag course, in which case it is said to be *forked;* or as broad flashes, often the reflection of distant forked lightning, when it is known as *sheet* lightning; or, more rarely, as a ball of fire, moving much more slowly, and remaining visible for some seconds.

Thunderstorms often occur entirely within the atmosphere, when differently charged clouds approach and discharge.

Distribution.—Within the sweep of the trade winds, in the polar regions, and in rainless districts, thunder-storms are very rare; in the calm belts they are frequent and violent. They are more terrible among mountains than on plains, and are extremely violent at the change of the monsoons.

Magnetism. *Nature.*—Magnetism is a force closely allied in nature to electricity, but chiefly confined to iron and some few other metals, and to the earth. The magnetism of the earth is called *terrestrial* magnetism; and its various operations may be best understood by observing its action upon a magnetized bar of iron or needle.

If a bar of iron be carefully suspended by its centre it will, of course, be quite horizontal, and remain directed to any point to which it is turned. If now this bar be magnetized, two peculiar features are at once made apparent. (1) The bar will only point in one direction, nearly north and south; and if the end which points to the north be directed to the south, it will immediately turn round, and, after a few vibrations, come to rest in its former position. This end is called the *north*, and the opposite end the *south pole* of the bar. (2) The bar no longer preserves its horizontal position, but the north pole inclines, or *dips*, as it is called, to the horizon at a certain angle.

We have said the magnetic needle points *nearly* due north and south. The deviation from that position is called the *declination* of the needle; and it is said to be east or +, and west or —, according to the direction of its declination.

The dipping of the needle is called its *inclination;* and it is said to be + when the north end points downwards, 0 when the needle remains horizontal, and — when the north end points upwards.

The force with which the earth acts upon the needle is called its *intensity;* and this is made up of two components—the horizontal intensity, relating to the declination, and the vertical intensity, relating to the inclination. The two together are termed the *total intensity*.

Representation. Like the distribution of temperature, the magnetic phenomena of the earth are best illustrated by series of lines. Those passing through places having the same declination are called *isogonal*[1] *lines;* those showing equal inclination are *isoclinal*[2] *lines;* and those passing through stations having the same intensity are called *isodynamic*[3] *lines*.

The distribution of these various lines over the surface is far too complicated to admit of treatment in an elementary work of this character. We will, however, briefly touch upon their more prominent features, commencing with—

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[1] Gr., *isos*, equal; and *gonia*, an angle. [2] Gr., *isos;* and *klino*, to bend. [3] Gr., *isos;* and *dynamis*, power.

1. *Isogonal Lines.*—The globe is divided into two hemispheres of unequal size by a *line of no declination*, passing through the poles, and roughly inclined to the equator from N.W. to S.E., at an angle of about 70°. The smaller compartment includes the north-eastern portion of North and South America, the Atlantic, Europe, Africa, and Western Australia. The declination is everywhere westwards throughout this area. The larger compartment, in which the declination is to the east, includes the rest of the globe, except an oval space embracing Eastern Siberia, Japan, the Yellow Sea, and part of the sea of Ochotsk. Within this singular area the declination is again westward.

The whole of the isogonal lines are sweeping westward in the northern, and eastward in the southern, hemisphere; the result being that lines of less western declination sweep successively any given place. Take, for example, Greenwich. Prior to the years 1657 to 1662 the declination there was to the east; during those years it was nothing; then it began to be to the west, and gradually increased up to 27° at the beginning of this century. It has since been decreasing.

2. *Isoclinal Lines.*—The line along which there is no declination is called the *magnetic equator;* and the points where the needle is vertical, the *magnetic poles.* The former does not coincide with the terrestrial equator, but is inclined to it at an angle of 12°, cutting it in long. 3° and 173° W., with a great bend to the south in the western Atlantic. The magnetic poles were both determined by Sir J. C. Ross. The northern pole is situated in lat. 70° N., long. 97° W.; the southern pole in lat. 75° S., long. 154° E.

3. *Isodynamic Lines.*—The equator of minimum in-

tensity is inclined to the terrestrial equator at from 12° to 14°, and cuts it at long. 32° E. and 148° W. As in the case of the magnetic equator, there is a deviation to the south on the west of the Atlantic. There are four points of greatest intensity, two in each hemisphere. In the north, one of these points is situated in North America, south-west of Hudson's Bay; the other in Siberia, in 120° E. long. In the south, one is in the South Atlantic, in lat. 20° S., and long. 36° W.; the other in 60° S. lat., and 131° E. long. The South Atlantic point has the least intensity, the other southern focus the greatest intensity; and the American is stronger than the Siberian focus.

Auroras.—In the extreme north and south, beautiful lights of rosy, golden, and emerald hues stream upwards from the polar horizon, or hang as a fairy curtain suspended in the sky. These appearances are called *auroras*. That in the north is known as the *aurora borealis*,[2] while that of the south is called *aurora australis*.[3] If we draw an oval round the north pole, through Iceland, the North Cape, the Gulf of Obi, Northern Siberia, the mouth of the Mackenzie River, the centre of Hudson's Bay, and Nain, it will include the region where the greatest number of auroras occur annually, the average number being forty. The southern region has not yet been mapped out. These auroras are closely connected with the magnetic forces of the earth.

It has recently been determined that auroras occur simultaneously in both hemispheres.

Magnetic Storms.—Occasionally great disturbances in the magnetic forces occur, which are called *magnetic storms*. They extend over immense areas at the same time, having been felt simultaneously at Toronto, Cape Prague, and Hobart-town. They are found to have a relation with the spots on the sun,

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[1] *Gr.*, the morning. [2] L., northern. [3] L., southern.

being most intense when the solar spots are most numerous. They have a periodicity of five years, corresponding with that of the sun spots.

CHAPTER IX.

LIFE.

Introductory Remarks.—The organic world is divided into two great kingdoms, the animal and the vegetable. The division at first sight appears to be one concerning which no doubt could arise; but when we descend to the lowest forms of life, it is seen that these kingdoms are separated by no distinct line, but that they merge so gradually into each other, that whole classes appear to hover on the confines, and to belong to neither. In this, as in all other cases, we see that nature has no hard boundaries, no harsh lines, but that a softening blending exists between its various members.

In speaking of animals and plants, we group together those forms which possess much in common as *genera*,[1] and again split up genera into *species*. Thus the lion, the tiger, and the cat, possess a vast number of features in common, and belong to the same genus; but they each possess differences of sufficient magnitude to authorize our considering them as distinct species.

We cannot, however, draw a line round species, either of animals or plants, so intimately are they connected by some one or more points. This mistiness, if we may so call it, ceases to be puzzling when we consider how probable it is that all the species of a genus have descended from one parent form, and that the differences by which we now distinguish them, are but the characters of branches of the same family. Tracing our way backwards through the two kingdoms, we find connecting links at every step, which seem to point to the same story; that animals, whether jelly-fish, crabs, oysters, fishes, reptiles, birds, or mammals, have all descended from some four or five original forms at most, whose characters are lost in the darkness of primeval time. The vegetable world tells us the same story; and further, it may be that the study of those obscure forms lying between the two kingdoms may yet show that animals and plants have had the same origin, and that the magnolia and the man have sprung from a common ancestry.

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[1] *L.*, *genus*, pl. *genera*, a race.

The distribution of species leads us to the conclusion that all the individuals of a species have spread from some centre where they were originally produced. It is not to be taken for granted that species live in the country best fitted for their growth; but it appears that, to a large extent, their existence at all and their relative numbers are determined by their power to cope with other species living on the spot. The common canal-weed (*Anacharis alsinastrum*) in its native Canada was not remarkable for vigorous growth; but when introduced into England, it ran through the country with astounding rapidity, choking rivers and canals, and becoming an enemy of no mean strength to those who depended upon a channel for support. It is called by labourers the "poor man's friend," in the river Welland, for three men are now required to keep clear the stream, where, before, one was sufficient.

The mode in which islands and other portions of the earth were stocked cannot be here treated of; but we may remark that the same story is told of the existence of continents where the sea rolls, and of changes of climate, gigantic in their nature, that *geology* brings to our knowledge.

Plants.—Plants are dependent for their existence upon climate and soil. In the snowy fastnesses of polar regions little vegetable life exists, the grey lichen clothes the rocks, and a few mosses live out a stunted life. As we descend into the more genial climes, the variety, beauty, size, and number of the plants increase, till, amid the damp, hot regions of the tropics, so luxuriant and gorgeous is the growth, as to render their forests impassable to man, and almost to animals, save birds and insects.

The same thing is observable if, instead of travelling from the poles to the tropics, we ascend a mountain. If the mountain be situated within the hot region, we pass in succession through the same classes of vegetation, and, more wonderful still, the forms living upon the mountains in regions distant from one another are often closely allied. How came they there? How did they cross those intermediate regions where climate would inevitably destroy them? The answer is to be found in the pages of geology. Once, the earth was cold, and such plants spread over those intermediate tracts, and as the climate grew hotter they were driven higher up the mountain sides, till now we find them isolated by hundreds, perhaps thousands of miles from their brethren, flooded out with sunshine, and driven to the mountain tops for shelter.

But soil, as well as climate, is an essential to plant-life. For the luxuriance of vegetation is as dependent upon soil as upon climate. The loose sandy tracts lying within tropical Africa are as bare as the bleak rocks of polar lands.

General Distribution.—The earth has been divided into eight climatal regions, corresponding with certain isotheral lines, each possessing its own peculiar vegetation. These regions are, (1) the Equatorial, (2) the Tropical, (3) the Sub-tropical, (4) the Warm Temperate, (5) the Cold Temperate, (6) the Sub-arctic, (7) the Arctic, (8) the Polar.

1. *The Equatorial Region* is the region lying under the equator, and rising to an altitude of 2000 feet. It is also known as the *region of palms and bananas*, from the abundance of those plants. *Orchids* of wonderful beauty and strange forms abound; spices, such as *ginger* and *cinnamon*, are abundant, and delicious fruits, like the *pine-apple*, occur in plenty. Among the trees, the *baobab* is most remarkable, and the *mahogany*, *logwood*, and *ebony*, are the most valuable.

2. *The Tropical Region*, found also at the equator between 2000 and 4000 feet on the mountains, is named the *region of tree-ferns and figs*. Spices, such as *pepper*, thrive; flowers of brilliant hues abound; and useful vegetables, such as the *yam* and *sweet potato*, are plentiful. *Teak* is, perhaps, the most useful tree of the region.

3. *The Sub-tropical Region*, extending also between 4000 and 6000 feet on the equatorial mountains, is known as the *region of myrtles and laurels*. The last of the palms, the *date palm* and the *palmetto*, are here found. *Cactuses* and *aloes* abound; *heaths* are represented by numerous and beautiful species; and giant forest trees, such as the *Sequoia* of California, 500 feet high, the bark of one of which formed till recently one of the grandest objects in the Crystal Palace, as it was one of the most execrable monuments of Vandalism, and the *Douglas pine*, which towers a magnificent cone to nearly 300 feet, form a noble feature in the region.

4. *The Warm Temperate Zone*, occurring also between the heights of 6000 and 8000 feet at the equator, is the region of *evergreen trees*. The *orange*, *fig*, and *pomegranate*, thrive; and the flowers, though approaching the character of our own regions, still retain enough of luxuriant beauty to stamp them as *natives* of warmer zones.

5. *The Cold Temperate* Region, lying also between

8000 and 10,000 feet upon the equatorial mountains, is called the *region of deciduous trees*, for in it forest trees, such as shed their leaves in autumn, the *oak*, *beech*, *elm*, etc., are found in great plenty. *Firs* occur in large forests, and in the southern hemisphere the *blue-gum* abounds.

6. *The Sub-arctic Region*, reached between 10,000 and 11,500 feet in the tropics, is the *region of pines;* but the *willow*, *birch*, and *poplar*, thrive also. *Apples* grow with difficulty, and fruits are rare.

7. *The Arctic Zone*, attained between 11,500 and 13,500 feet at the equator, is the *region of rhododendrons*, whose beauty spreads a strange charm over the cold zone they inhabit, almost rivalling the splendour of tropical forms. The flowers, though not so luxuriant, are of remarkable brilliancy. The *firs* are the only trees, except the dwarfed and stunted *willows*, *alders*, and *birches*, that survive the rigorous winter.

8. *The Polar Region*, represented on the tops of the highest mountains as well as within its own peculiar district, is the *region of alpine plants*. No tree, no shrub, no plant whatever, rears its head above a few inches from the soil. The *willow* and the *birch* creep along the ground, and represent the only approach to woody-stemmed plants. *Mosses* and *lichens* thrive in abundance; and on the eternal snows themselves, vegetation is represented in the singular form known as *red snow*.

Plants are also classified into geographical regions, characterized by the prevalence of certain plants having a resemblance; but this is a subject for which, as for so many other points connected with the distribution of life, we must refer the student to larger works.

Marine Vegetation.—Seaweeds do not live indiscriminately at all depths, but certain forms are found to thrive only between high and low water mark. Others, again, are confined to a depth of between seven and fifteen fathoms; and yet others live only in deep water.

Marine plants are also distributed in regions, like their terrestrial brethren, but space forbids any enlargement upon the subject.

Distribution and Limits of Important Plants. *Trees.*—The north limit of trees is roughly that of the summer temperature (isotheral line) of 50°. Commencing on the north of the peninsula of Alaska, the line passes immediately south of the Great Bear Lake, through the centre of Hudson's Bay and the north of Labrador; thence through the south of Iceland and the extreme north of Norway; after which it bends south for a time, to the Arctic Circle, and finally makes a wide sweep through Asia, dropping below that circle on the extreme east.

Trees grow all over the lands of the southern hemisphere, excepting the distant southern continent.

Grain.—The north limit of cultivation of grain is nearly that of the isotheral of 55°. The following table shows the chief grains in the order in which they are met with, commencing from the north, together with the extremes of temperature within which they flourish, roughly estimated:—

Grain.	Isotheral.	Remarks.
Barley . .	55° to 70°	Widest geographical range.
Rye . . .	58° to 70°	Bread of Scandinavia and Russia.
Oats . .	58° to 72°	Largely used in Scotland.
Wheat . .	59° to 75°	Cannot grow in N. Scotland.
Maize . .	65° to 80°	Bread in Germany, France, and United States.
Rice . . .	80° ——	Chief food of India, China, and Japan.

Vine.—The vine ranges north to about 52° N. lat. *in the Old*, and 40° in the New World. Its southern limit is about lat. 40° S. The finest wines are produced between lat. 30° and 40°.

Animals. *General Distribution.*—The distribution of animals is determined by climate and food. The remarks made respecting the adaptability of species of plants to the places where they live, are equally true of animals. Thus, the horse, introduced from Europe, has spread over the prairies and pampas of America in vast herds, showing how fitted for the New World that animal is. No native horse is known in America; but, strangely enough, they once lived and died out, for their remains are still discovered as fossils in the superficial beds of South America.

We cannot enter upon even the slightest description of the distribution of fishes, reptiles, birds, or lower animals, for we have only space for a few words respecting the range of the chief *quadrupeds*.[1]

The animals of the arctic zone are not numerous, and they are either of the same or closely allied species in Europe, Asia, and America. This must necessarily be the case when we consider how closely connected the polar lands are, and how easily animals can travel in winter over the frozen ice-fields, or be carried involuntarily upon the floating ice. The greater number of the animals inhabiting this zone are fur-bearing; but reindeer and elks are numerous.

The lands of temperate zones being more separated, the animals there have not so close an alliance in species as those of the arctic zone, but the same general features prevail. Thus, the *aurochs*, or wild cattle of Europe, now extinct, save in one locality where they are protected by command of the Czar of Russia, are represented in North America by another species of the same genus, the *bison*, or "buffalo," of the hunters. The beaver extends over temperate Europe, Asia, and

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[1] L., *quatuor*, four, and *pes*, *pedis*, a foot; four-footed animals.

America. The Old World bears are represented by those of the New World; deer, hares, wolves, etc., in like manner are represented in both hemispheres. The goats occur in the mountain districts of both regions.

In the tropical zones again a rough parallelism may be maintained between the animals of the two worlds. Thus the *lion* is represented in America by the *puma*, the *tiger* by the *jaguar*, the *leopard* by the *panther*, the *elephant* by the *tapir*, the New World by the Old World monkeys. But these are only very rough comparisons, for the differences are usually of generic value. Polynesia possesses no animal larger than a hog.

Distribution of some of the Chief Animals.—Africa is the region of the *lion* and the *hippopotamus*, the *giraffe*, the *zebra* and *quagga*, and numerous antelopes; the *baboon* and the *gorilla* are African. The *elephant* and the *rhinoceros* have a wider range, being found over all Africa south of the Sahara, Hindostan, Further India, and Sumatra; the species differ in different localities. The *tiger* extends from Hindostan to the Caspian, thence to Lake Baikal, and south, through the peninsula of Corea, to Sumatra. It is, however, occasionally found as far north as Barnaul on the Obi, in Siberia. The *kangaroos* are confined to Australia, which island also possesses the peculiar *ornithorhynchus*, so named from its peculiar bird-like bill. South America possesses the *llama*, the New World equivalent of the camel.

Man.—Professor Huxley has divided the varieties of man into two great classes, according to the character of the hair—the *Ulotrichi*,[1] having crisp, woolly hair; and the *Leiotrichi*,[2] having smooth hair.

1. *Ulotrichi.*—The colour in this race varies from yellow and brown to the darkest tint known in the human skin, usually called *black*. The hair and eyes

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[1] *Gr., alos*, crisp, and *trichios*, hair. [2] Gr., *leios*, smooth.

are dark. The skulls are long, or *dolicocephalic.*[1] The chief varieties are—

Negroes, extending from the Sahara to the Cape.

Bushmen, inhabiting the Cape district. They are remarkable for their low stature, the males seldom exceeding four feet in height, and the females are much shorter. There is a remarkable tendency to develop great masses of fat upon the buttocks.

Negritos, inhabiting the Andaman Islands, Malacca, the Philippines, and Papua, the islands as far south as New Caledonia, and Tasmania. Of these the Andaman islanders alone have broad, or *brachycephalic*, skulls.

2. *Leiotrichi*, divided into four classes.

(*a*) The *Australoid Type*, with dark skin, hair, and eyes; long wavy black hair of fine silky texture; dolicocephalic skull; prominent brow-ridges; nose broad, but not flat; jaws heavy and projecting, and lips very coarse and flexible.

The *Australians* and the hill-tribes of the Deccan (*Coolies*) exhibit these characters, and the *ancient Egyptians* possessed them also.[2]

(*b*) The *Mongoloid Type.* Skin yellowish or reddish brown; eyes and hair black, the latter scant upon the body and face, but long and straight on the scalp; skulls vary from dolicocephalic to brachycephalic. From Lapland to Siam, this type prevails, and this section has broad skulls. The *Chinese* and *Japanese* have long skulls. The *Malays*, with broad, and the *Dyaks*, with long skulls, belong to this class, as do also the *Polynesians*, the *Maories* of New Zealand, and the *Eskimo* and American races.

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[1] Skulls are said to be long, or dolicocephalic, when the breadth is less than eight-tenths of the length, and brachycephalic when more than that amount. Gr. *dolikos* long, *brachys* broad, *kephalon* a skull.

[2] In the museum of the Khedive of Egypt at Boulak, near Cairo, a bomerang is shown from the pyramids of Sakkarah, thus bearing evidence of the truth of the above classification.

(*c*) The *Xanthochroic*[1] *Type*, or *fair-white*, have clear, transparent skins, blue or grey eyes, abundant fair hair. Skulls vary from dolicocephalic to brachycephalic. The *Slavonians*, *Teutons*, *Scandinavians*, and fair Celtic-speaking nations, belong to this division, which extends into North Africa and West Asia.

(*d*) The *Melanochroic*[2] *Type*, or *dark whites*, have pale complexions, dark eyes and hair, skulls generally long, but sometimes broad.

The *Iberians*, "black Celts," of Western Europe, dark-complexioned whites of the Mediterranean, West Asia, and Persia, are included in this class. They are probably a mixture of Australoids and Xanthochroi.

Man's Influence.—Man's influence upon the earth is of a twofold nature: his influence upon life, and his influence upon inanimate nature.

Influence upon Life. (1) *On Animals.*—This may be discussed under two aspects: (*a*) *Preservation*, in the case of useful animals, such as the ox, horse, dog. (*b*) *Extermination*, or the destruction of animals dangerous or annoying to man, such as the wolf; or useful for food, as the deer.

(*a*) *Preservation.*—Animals have been domesticated from the earliest times. The rude pre-historic people, who used the flint implements so plentifully discovered within the last few years, are known to have domesticated the *dog*, *ox*, *horse*, *goat*, *sheep*, and *hog*. The domestication of these animals dates too far back to be traced; but it is certain that they have for ages been made subject to man over the greater portion of the globe. To such an extent has domestication altered the characters and habits of animals, that differences of variety, such as the dray-horse and the hunter, have been produced; differences so great that, had they occurred in nature, they would have been deemed sufficient to constitute distinct species.

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[1] *Gr.*, *xanthos*, yellow, and *chroma*, colour. [2] Gr., *melanos*, dark.

(*b*) *Extermination.*—The extermination of useful animals, such as the *beaver*, *deer*, etc., is owing to the great demand for the skin in the one case, and to the fascinating pleasures of the chase in the other, combined with the spread of cultivation, driving the native animals into more confined areas. In this way large districts have been cleared of their former denizens. Other species are in process of extermination; thus the *deer* and the *bison* are becoming rarer every year in North America; and no country can be named where fur-bearing, or other useful animals, or even animals valuable for the chase, are not being steadily destroyed.

Wolves, *bears*, *lions*, *tigers*, and such animals as are dangerous to man or destructive to his property are speedily exterminated in the neighbourhood of towns or driven to less frequented spots. Thus, England has long been depopulated of *wolves* and *bears*, and the *fox* would have shared the same fate had it not been preserved for the purposes of sport.

(2) *Influence on Plants.*—Plants have been cultivated from remote ages; and the perfection to which they have attained is the result of long and continued selection of the best varieties. That the valuable characters cultivated plants possess are really the result of man's influence, is evident from the fact that no single useful plant, such as wheat, cabbage, or potato, has ever been found in newly-discovered regions, except in a state of cultivation. So far has modification been carried, that the original forms of most of our cultivated plants are unknown.

Influence upon Inanimate Nature.—Man's influence upon inanimate is greater than upon animate nature, for it is more directly under his control. This influence is either—(1) *Direct*, as in clearing forests, reclaiming waste lands, enclosing marshes, etc.; or (2) *Indirect*, as in the unforeseen effects upon climate caused by the above influences.

1. *Direct.*—So soon as man becomes civilized, and commences to till the soil, he begins to cut down trees. This is natural in the case of thick forests, which rapidly disappear before the march of civilization, but is not so excusable in some other cases, where trees are ruthlessly destroyed, even in thinly-wooded districts. Forests are often obliterated by accidental fires, as in the great forest fires which raged in the northern states of America last autumn (1871), when Chicago was consumed; but the loss from this cause is not so great as from cultivation, for in the latter case, no chance of reproduction is possible. Europe was once a vast forest; now it is sparsely wooded; immense forests have been cleared in America and in other parts of the globe.

Waste lands are continually being reclaimed, and marshes drained and cultivated, as in our Fen-land, where about 800 square miles have been brought under tillage, and large tracts of land have been reclaimed from the sea, as in Holland and our eastern coasts.

2. *Indirect.*—The indirect effects of operations such as the above upon climate, have been as remarkable as they were unexpected.

The clearing of forests acts powerfully in modifying climate. Forests "regulate rainfall, by preventing too rapid evaporation from the soil, and creating a stratum of cooler air above it," and by equalizing temperature, causing the nights to be warmer and the days cooler, and rendering winter less rigorous and summer less scorching. Where, as in Spain, Italy, India, etc., they have been destroyed, the fertility of the district has been diminished; for the rain, instead of falling in moderate quantities on many days, descends in torrents within a short space of time, sweeping away the soil, and causing the country to become parched and infertile. In places, such as Algeria and Egypt, *where planting* has been much resorted to, rain now falls much more abundantly than before, and the soil is becoming more productive. No better example of the effect of forests upon climate can be found than that of Piazza Torre, in Italy, where the wood, being used to produce charcoal for iron-furnaces, was at length all felled, and the climate so increased in severity, that the maize no longer ripened. "An association, formed for the purpose, restored the forest, and maize flourished again in the fields of Piazza Torre."

Irrigation, that is the artificial watering of the land by canals, has in some cases greatly diminished the amount of water carried to sea by rivers. Instances of this kind are not uncommon in Spain, in Lombardy, Turkey, etc., and the case of the rivers falling into the Caspian has been already noticed (p. 114).

Conclusion.—*The Continents.* We have described the various agents at work upon the surface, which make the earth what we now find it. We have seen how important the movements of the globe are in producing the varied alternations of day and night, of spring, summer, autumn, and winter; we have learned how all-powerful the sun is, in affording us the light and heat by which alone life can be supported; we have seen how that light is dispersed and rendered useful by the intervention of the atmosphere, and how the combined effect of atmosphere and solar heat results in the production of rain, of snow, and hence of rivers; and lastly, we have dwelt upon the face of the globe as teeming with life under myriads of forms and conditions.

But the surface of the earth at present, is not the surface of the past. It is varying always, changing always, never the same. The rain is perpetually falling upon the land, washing fragments of soil and rock into the rivers; the rivers are continually grinding their beds and wearing them away; and the sea is ever gnawing at the shores, and swallowing all that is carried down by the rivers. Nor is this action to be ignored, for it is estimated that the whole of the land-surface of the globe could be reduced to the sea-level by the existing rivers in about six million years. But this wearing down is to some extent compensated for by the gradual elevation of portions of the earth, through the agency of heat. Water is continually striving to reduce the land beneath the waves; and it is only by the intervention of fire that it is prevented from accomplishing its object.

Hence we see how the face of nature is ever changing; and as the depression, as well as the elevation, of land may be produced by the action of heat, we see how probable it is that continents have once existed where now blue water lies, and that oceans have rolled over the lands of both hemispheres.

The science of geology renders this probability a certainty, for the rocks themselves tell us of these changes, and tell us further, that they have not happened once or twice, but many times in the world's history. And, more wonderful still, within these rocks are entombed the remains of animals and plants that lived upon those wasted continents or in those ancient seas; and we find them of strange shapes, such as no longer exist, but all pointing to the same story, that throughout vast ages, earth has been peopled with living beings; and that the present state of things is but the last of a long series of changes. In other words, geology is the physical geography of past ages, or physical geography the geology of the present.

The time necessary to produce these changes is so vast that the mind cannot grasp it. Astronomy brings man in contact with the Infinite, Geology with the Eternal, and both are attributes of GOD.

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